Water Power

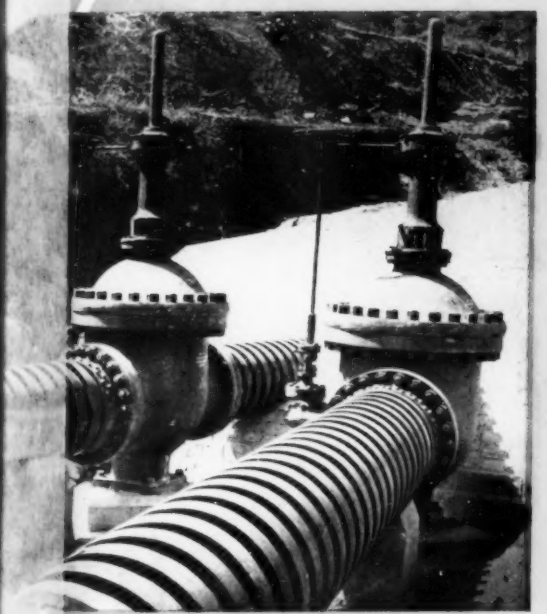
INTERNATIONAL DEVELOPMENT OF HYDRO-ELECTRIC POWER

PRICE 2/6 MARCH 1956

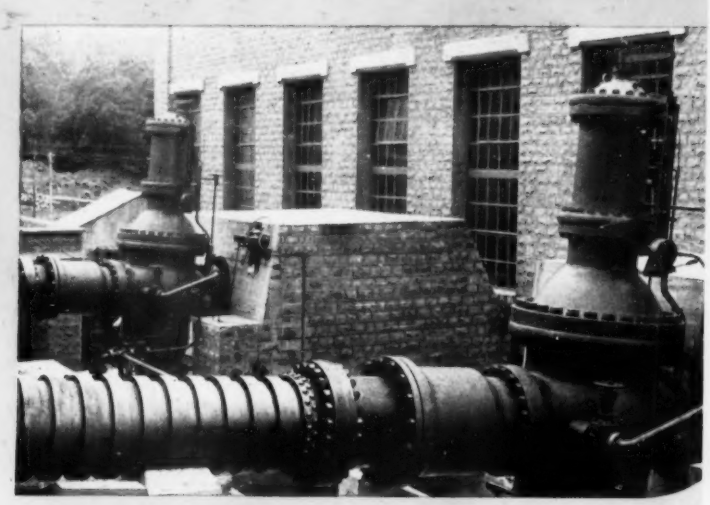
TEXAS TECHNOLOGICAL

Control Equipment

at the Dam ★



in the Pipelines ★



★ at the Power House

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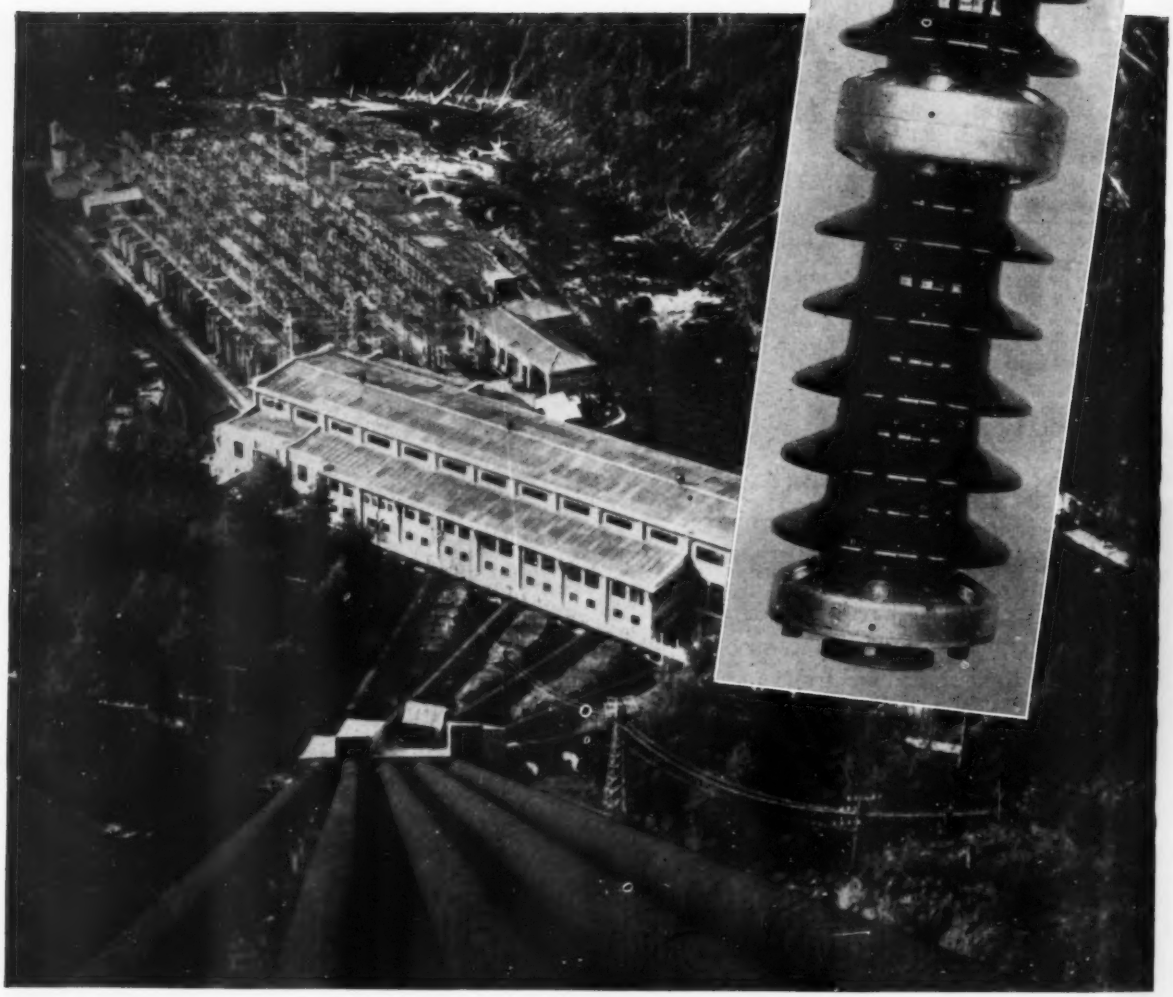
S.P.P. Post Insulators

were used for the

Tarraleah Sub-Station, Tasmania



The Sub-station at Tarraleah, Tasmania, is one of the many 110 kV. and 88 kV. sub-stations on the Hydro-Electric Commission's system equipped throughout with S.P.P. Cylindrical Post Insulators.

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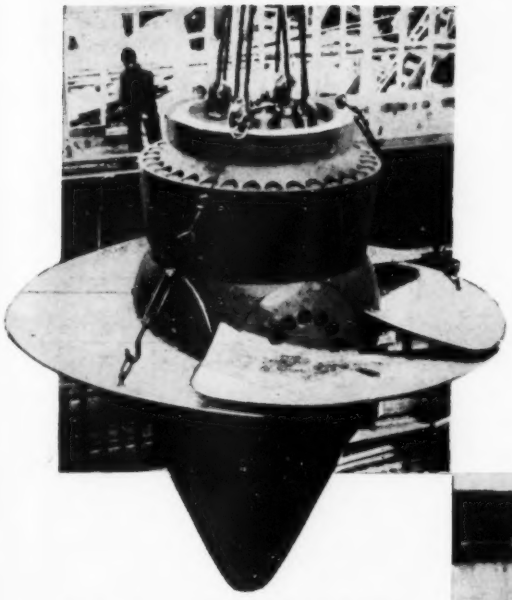
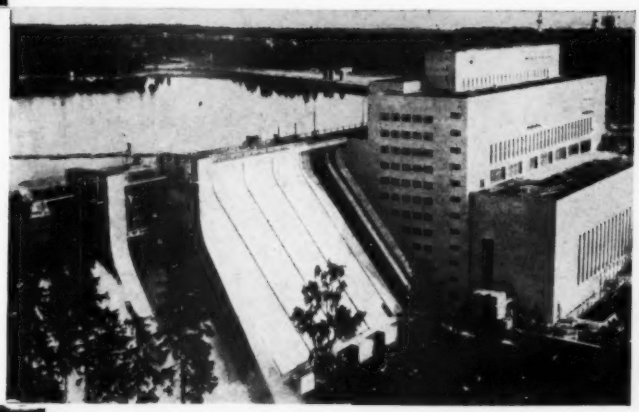
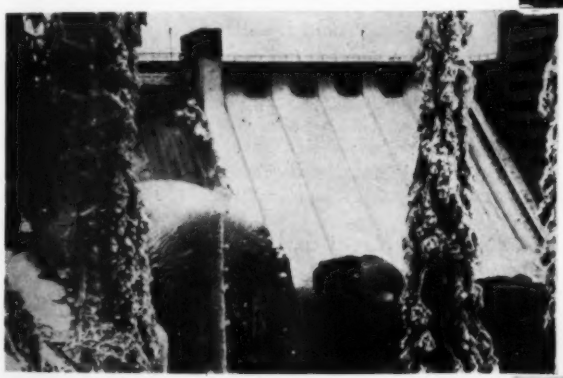


large turbines for large projects

The construction of hydro-electric schemes is an expensive business and it is essential that the cost of the plant is kept as low as possible. To achieve this the size of individual turbines is increasing so that fewer units in the power station are necessary. This also helps to achieve high efficiencies from the turbines.





As an example, the Pyhakoski plant in Finland is equipped with Kaplan turbines, each developing 51,200 BHP under a nett head of 32.8 metres (107.5 ft.). The photograph at the top of this page shows a 4,300 m m (14'—1") dia. Kaplan runner built by Boving being lowered into position.

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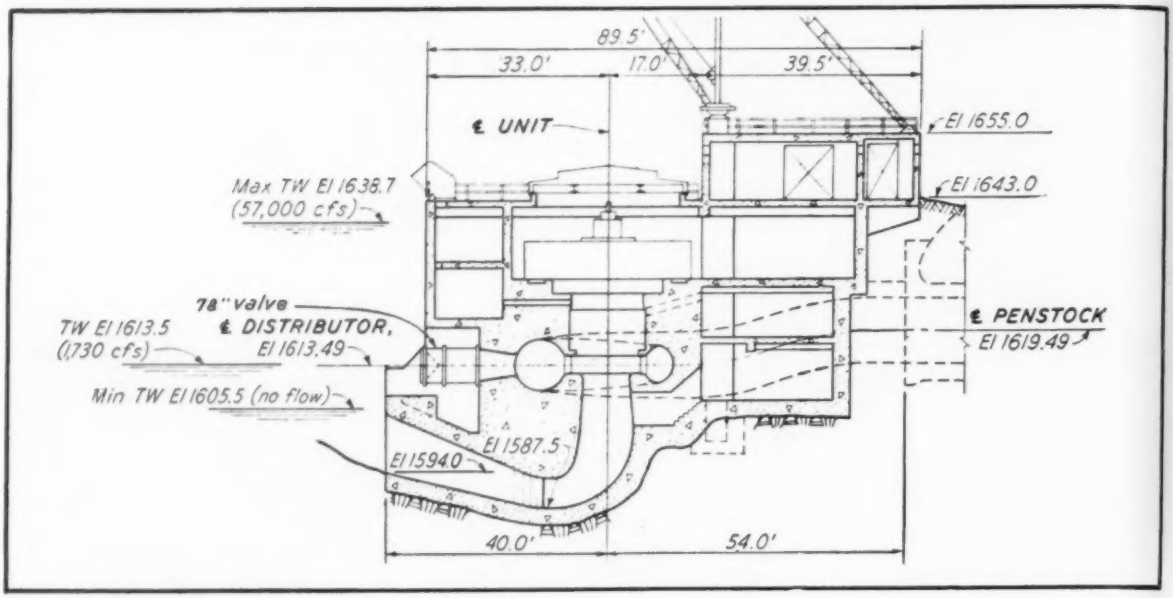
TVA Installs *Another* Leffel Turbine

Nottely Dam Power Plant — a progress report as of the end of 1955



Completely assembled turbine except for riveted scroll case.

Powerhouse excavation and draft tube forms in place.

Assembled scroll case in position from above.

In the new hydroelectric power plant on the Nottely River near Murphy, North Carolina, the TVA is now completing the installation of another efficient Leffel turbine.

Nottely Dam, of the rock and rolled earth fill type, was completed in 1942, without a power unit. Installation of the No. 1 power unit was authorized in 1951 and a Leffel turbine was selected to drive the generator.

The turbine is rated to develop 21,000 HP under a net head of 124 feet at 180 RPM. The specific speed of the turbine at rating is 63.2 RPM. The operating head varies from 76 feet to 166 feet.

Other Leffel turbines installed by the Tennessee Valley Authority are located at Chatuge Dam in North Carolina and Wilbur Dam in Tennessee.

The efficient design and rugged construction of the Nottely unit—backed by 94 years' of experience in the hydraulic turbine field—make it typical of the notable hydraulic turbines built by Leffel for hydroelectric power projects throughout the world.

Leffel engineers are trained in design, construction and adaptation of the turbine which will most efficiently and economically meet the needs of each power plant development, whether it is a completely new installation or part of an expansion of rehabilitation program.

Before you plan your next turbine installation, be sure you have the complete story on rugged, efficient Leffel turbines. Write, wire or phone . . . you'll get action fast.

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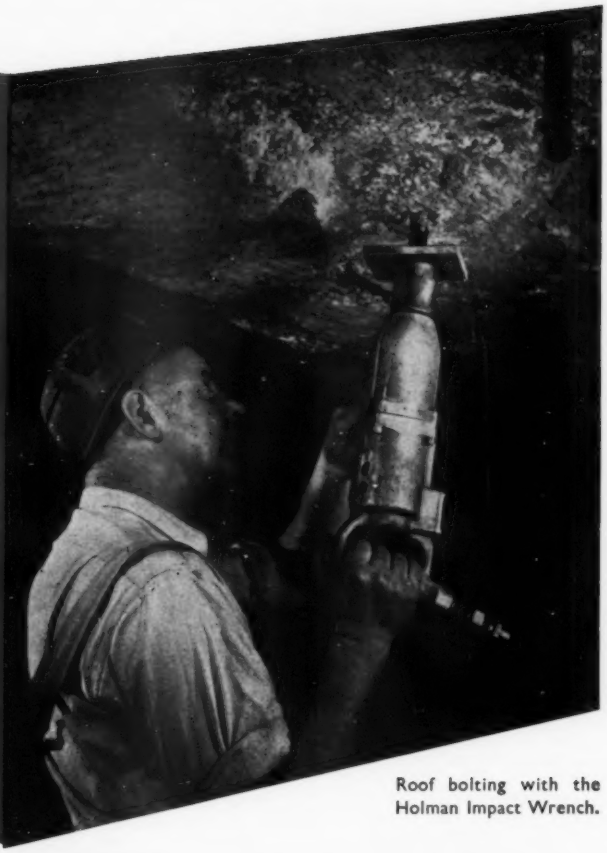
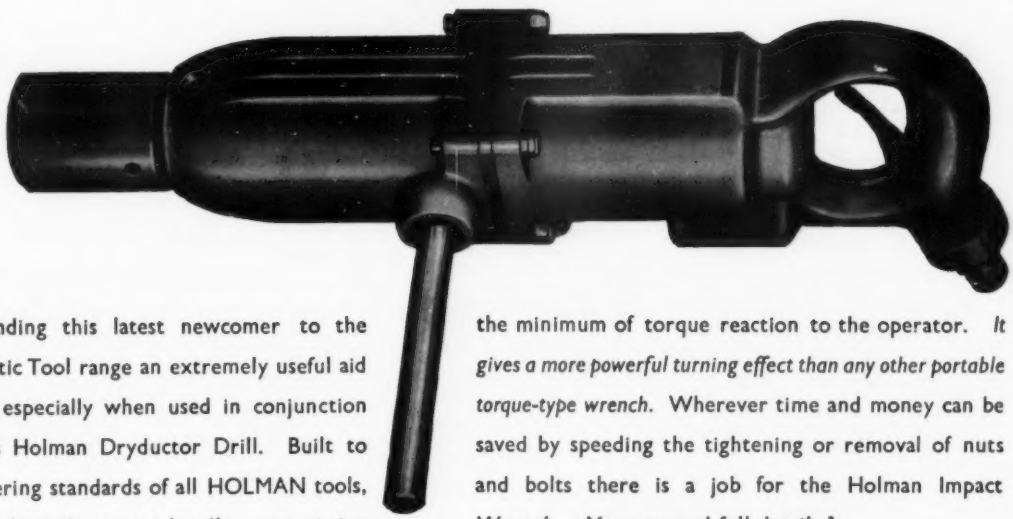


Roof bolting with the Holman Impact Wrench.



MINERS are finding this latest newcomer to the Holman Pneumatic Tool range an extremely useful aid in roof bolting, especially when used in conjunction with the famous Holman Dryductor Drill. Built to the high engineering standards of all HOLMAN tools, it is compact, light and easy to handle, transmitting the minimum of torque reaction to the operator. *It gives a more powerful turning effect than any other portable torque-type wrench.* Wherever time and money can be saved by speeding the tightening or removal of nuts and bolts there is a job for the Holman Impact Wrench. May we send full details ?

IMPACT WRENCH Size 404, powered by Holman Vane Type Motor. Suitable for ¾-in. heavy duty and 1-in. normal duty. Output Spindle takes 1-in. square drive chucks. Length 16 in. Weight 21 lb.

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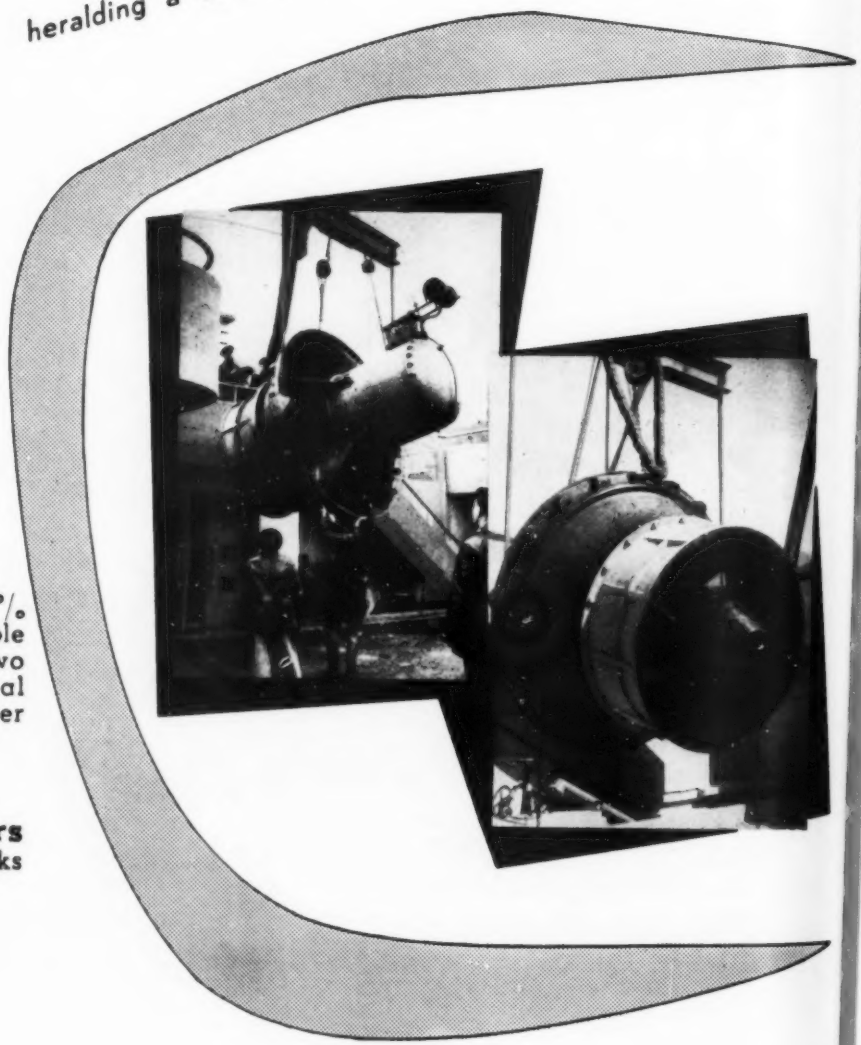

A saving of 40 % was made on the whole installation by using two submerged type axial flow units (1085 H.P. under 23 ft)

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Practical research on electrical equipment at the high-voltage testing station

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Discourse on Drilling Rock

There must still be quite a lot to learn about rock-drilling, because there are many schools of thought on methods of approach, techniques, and equipment. But with any method the important feature is the final cost.

Now, a rock-drill with a very fast speed of penetration might well be accepted by some as the be-all and end-all of drilling, on the assumption that this determines the rate of progress and, therefore, eventual cost. Is this, in fact, true? If it were, then a rock-drill could be designed which would put all others in the shade for speed. But rest assured it would just as quickly break itself to pieces, and the cost of keeping such rock-drills in operation would 'bankrupt' a job long before it reached completion.

On this analysis, it seems that the steady consistent rate of progress undoubtedly proves faster in the end—and certainly very much cheaper—than all the record-breaking efforts that we rock-drill manufacturers care to attempt.

This explains why the CP-32 and CP-58, which are certainly first-class rock-drills, used with SECO tungsten carbide tipped Swedish steels which have proved themselves to be without equal, continue to set up the best *overall* performance anywhere in the world.

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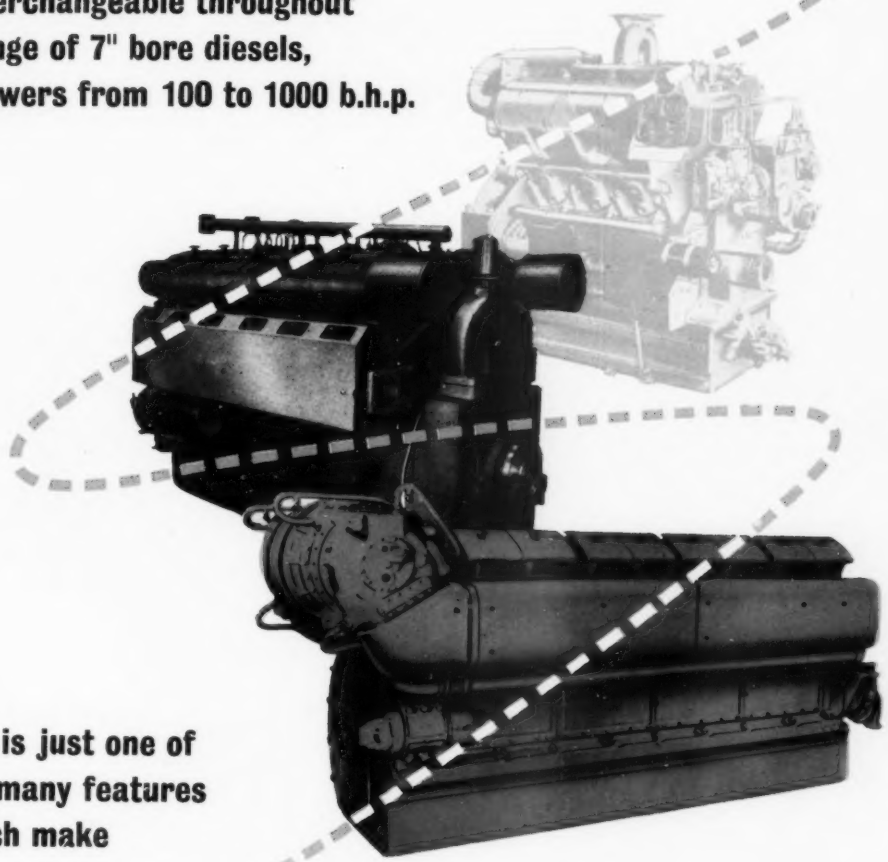

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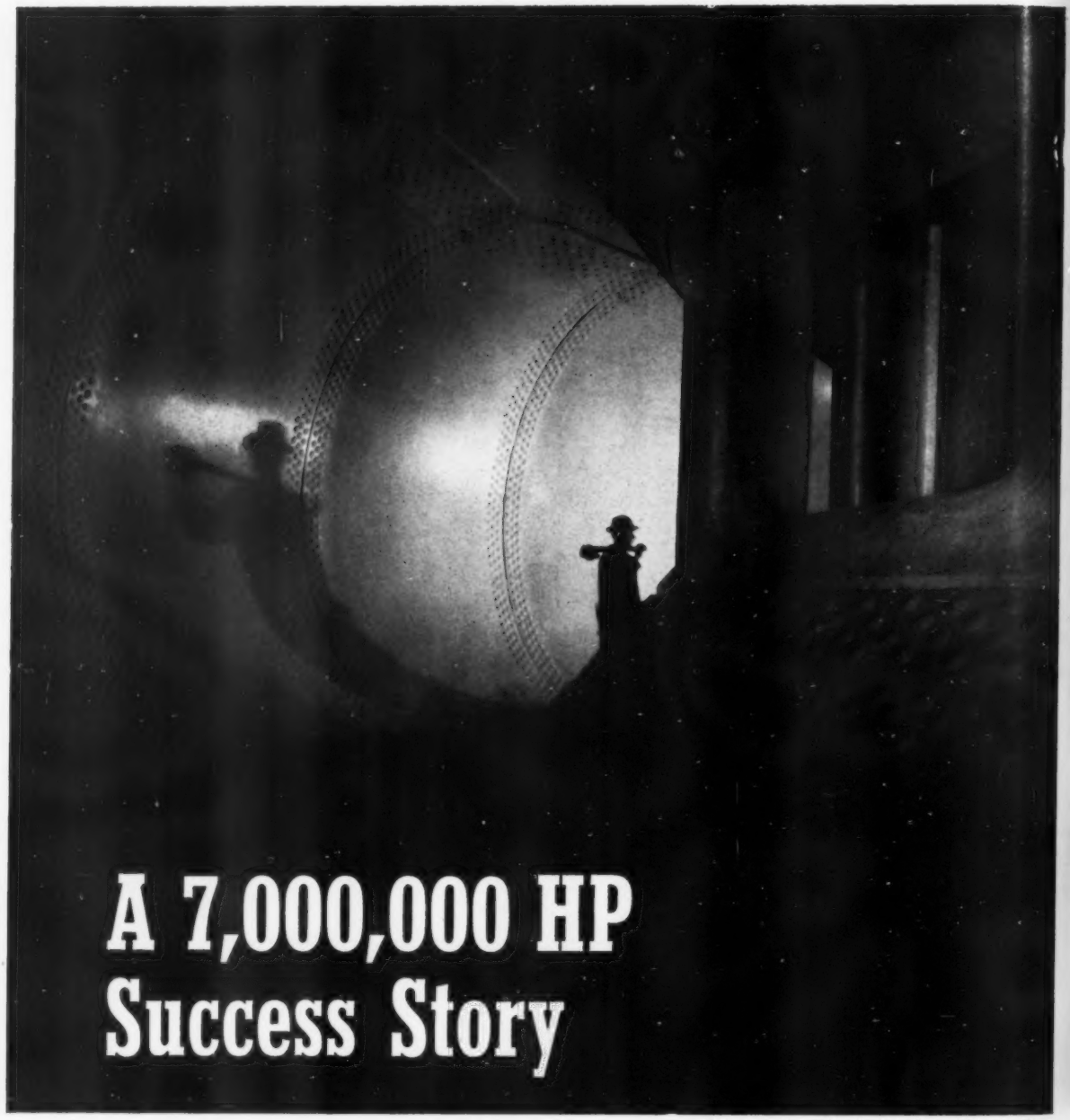

A 7,000,000 HP Success Story

Interior view of spiral casing at Norris Dam

Achievements of Newport News personnel in designing and building water power equipment during the past thirty years reflect a high integration of skill and production facilities.

Answering demands for hydraulic turbines rated as high as 165,000 horsepower and as low as 500 horsepower, this trained organization has successfully filled contracts with an aggregate rated output in excess of 7,000,000 horsepower.

Other essential equipment including penstocks, spiral casings, valves, pumps, gates and rack rakes are also designed and built by Newport News.

An illustrated copy of our booklet entitled, "WATER POWER EQUIPMENT," will be sent to you upon request.

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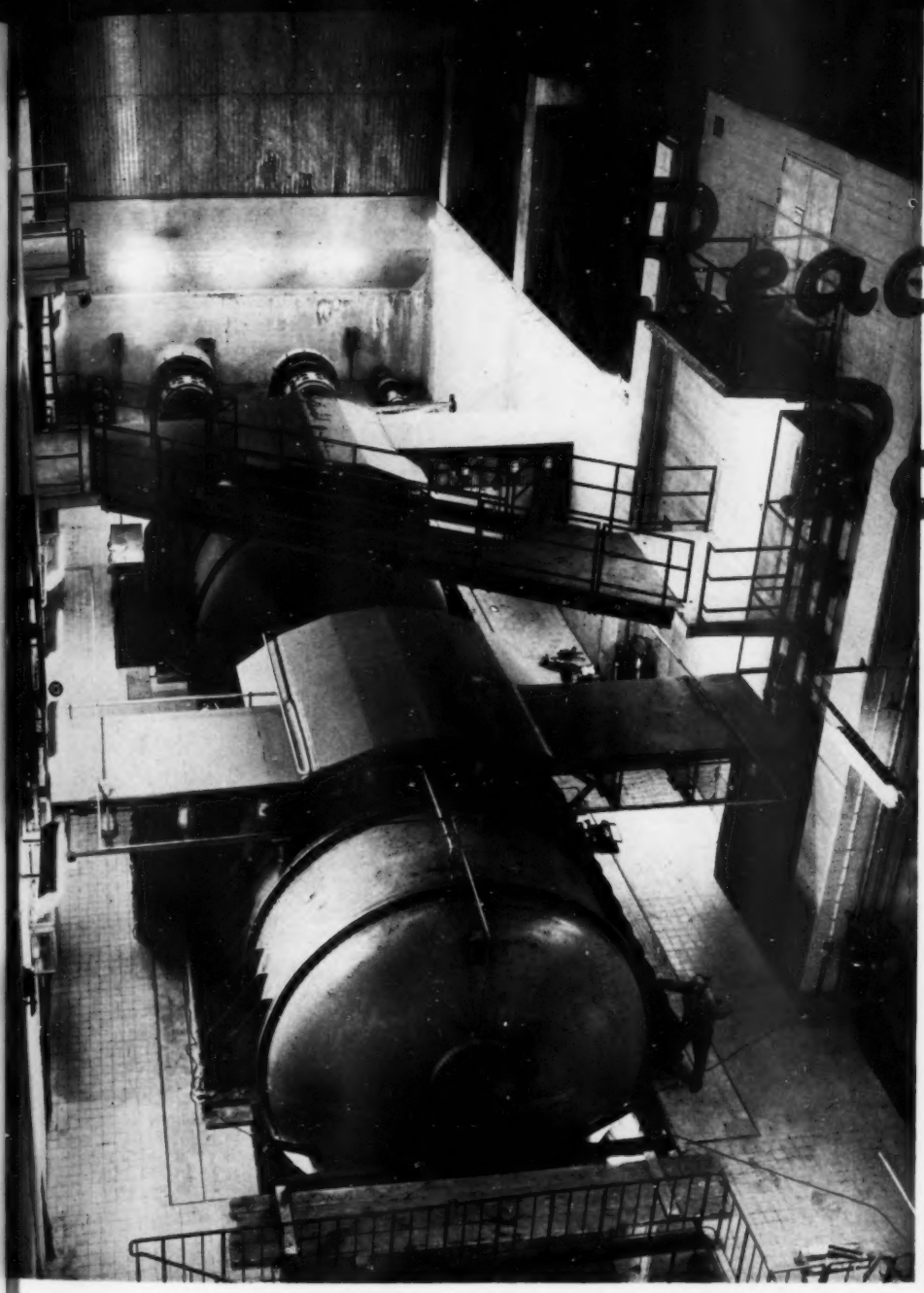

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Stability and voltage control of large high-voltage transmission systems require equipment for large amounts of reactive power.

For the Swedish State Power Board's 380 kV system with a total line length of about 1,700 miles, ASEA have supplied all the synchronous condensers, all the shunt reactors and two-thirds of the series capacitors.

The ASEA deliveries comprised, in all :

Synchronous Condensers	± 225 MVAr
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The picture shows a view of a subterranean station with two hydrogen-cooled condensers, each machine having the following main data :

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Map of Sweden showing the 380 kV transmission system

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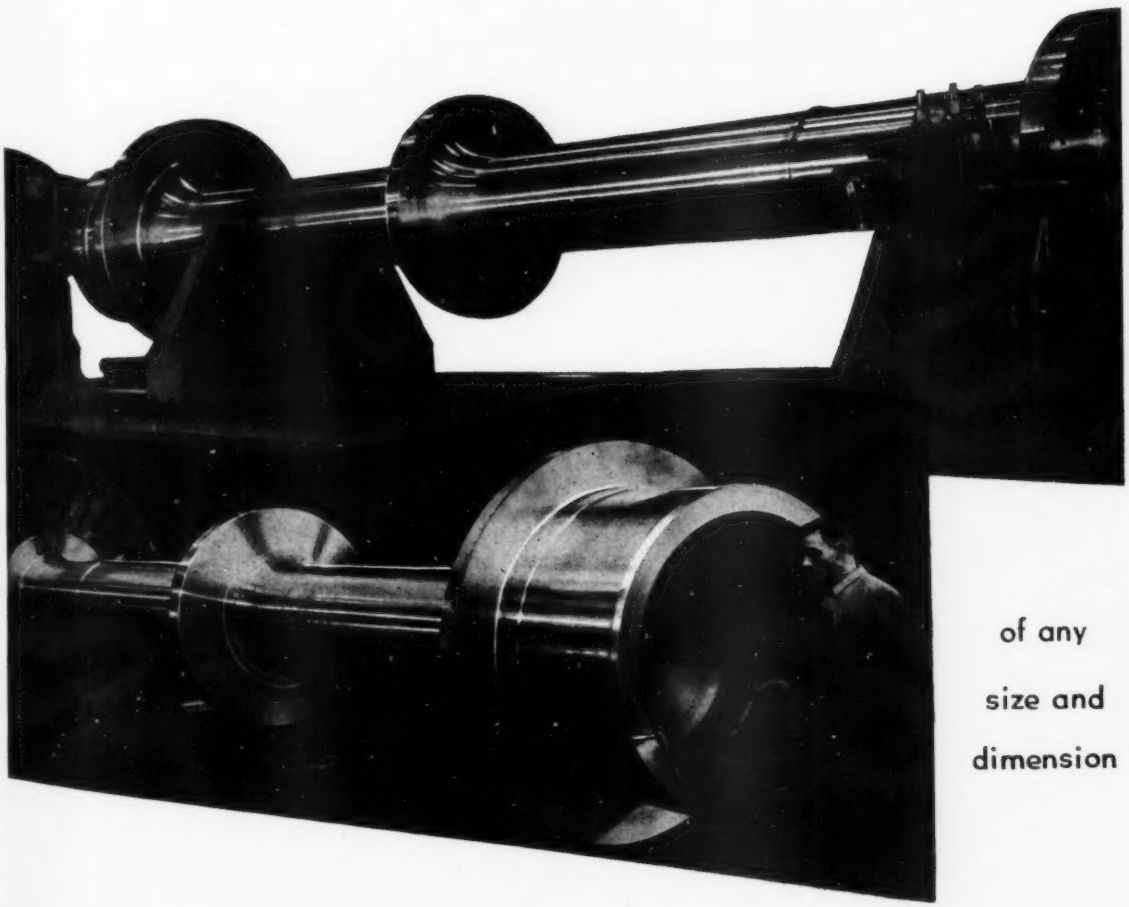

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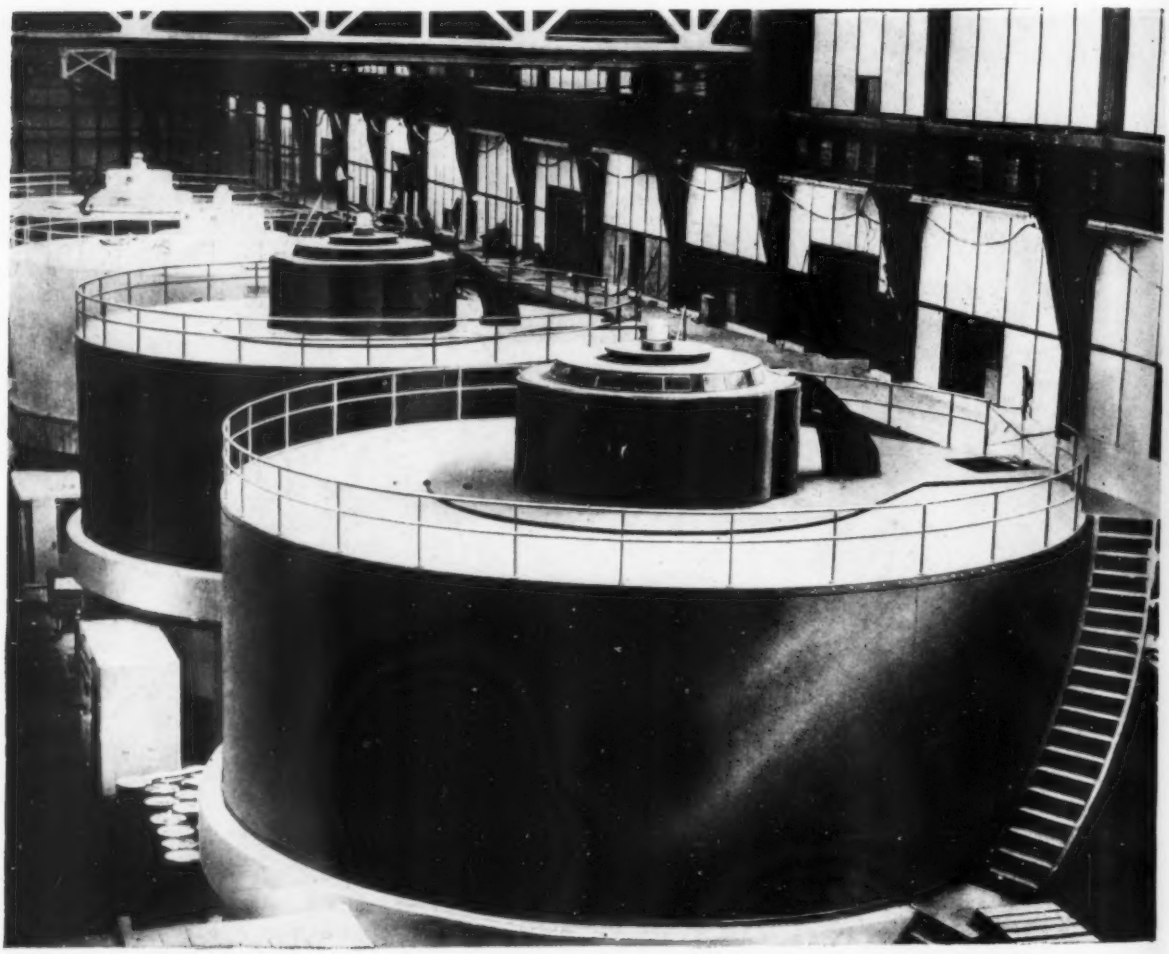

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TOSHIBA is proud of its brilliant achievement in the past. But it is even more proud of its willingness to face new industrial challenges. TOSHIBA awaits your valued patronage and is ever ready to serve you faithfully. Inquiries are very much welcomed.

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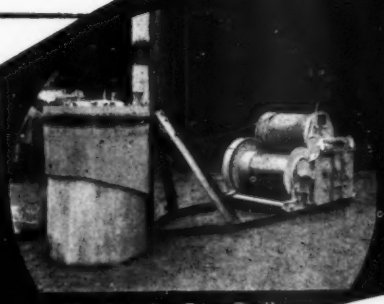

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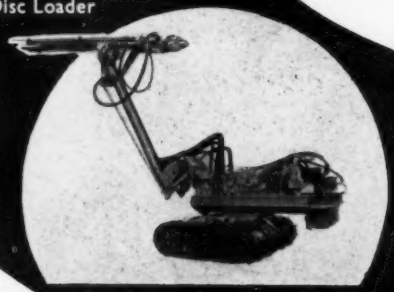

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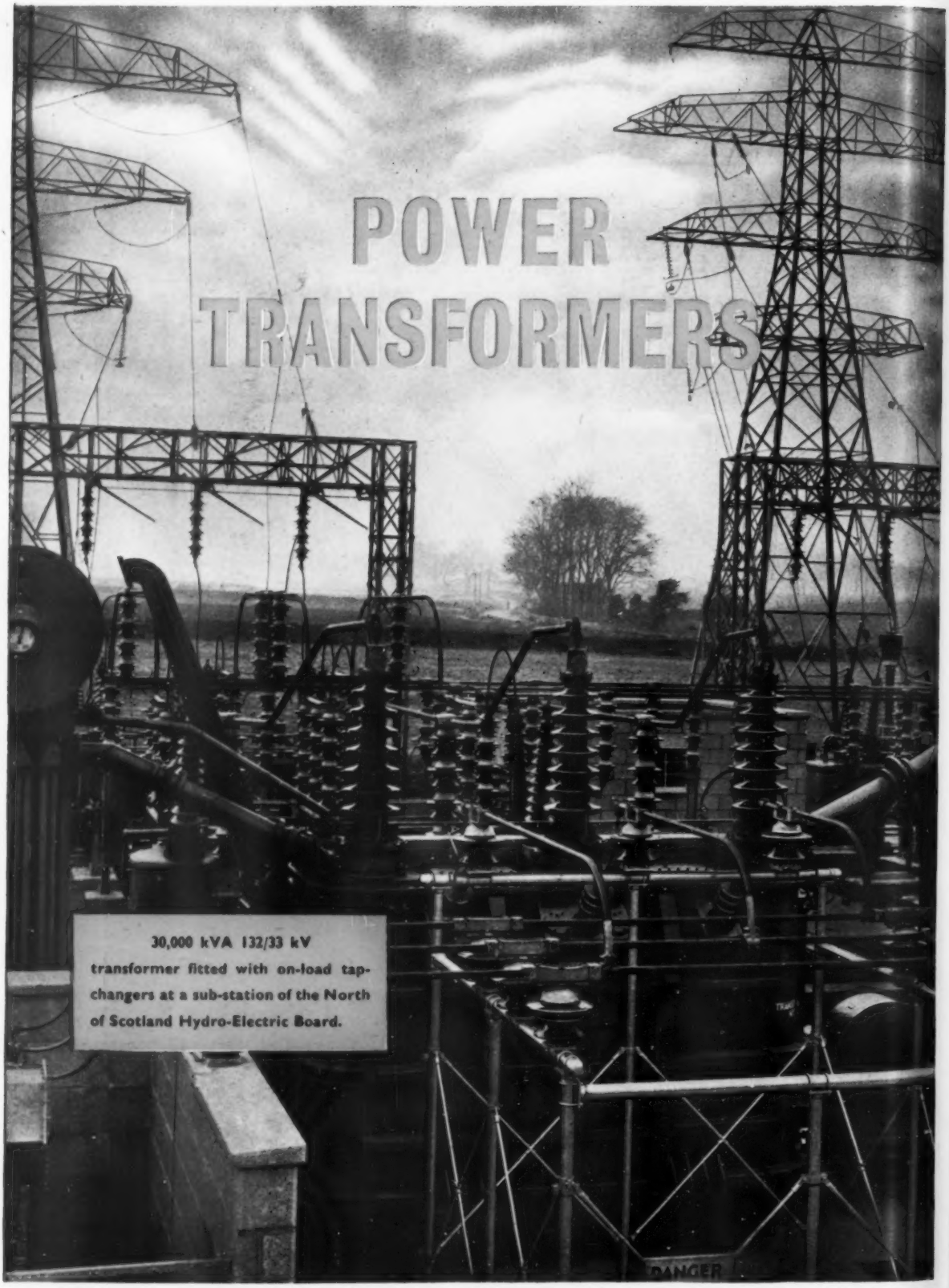
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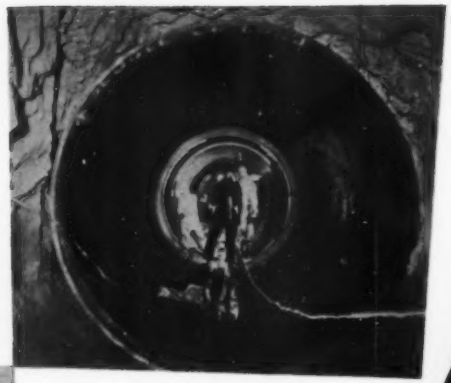

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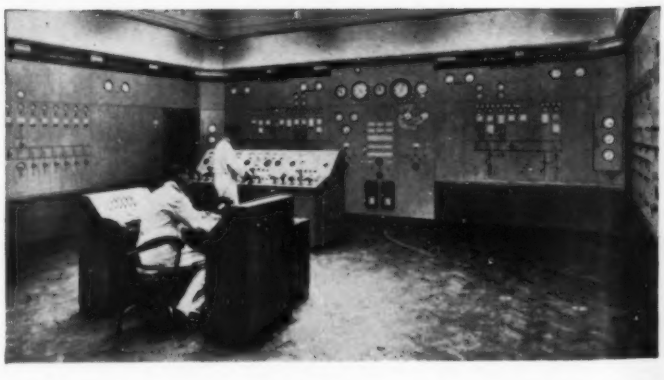

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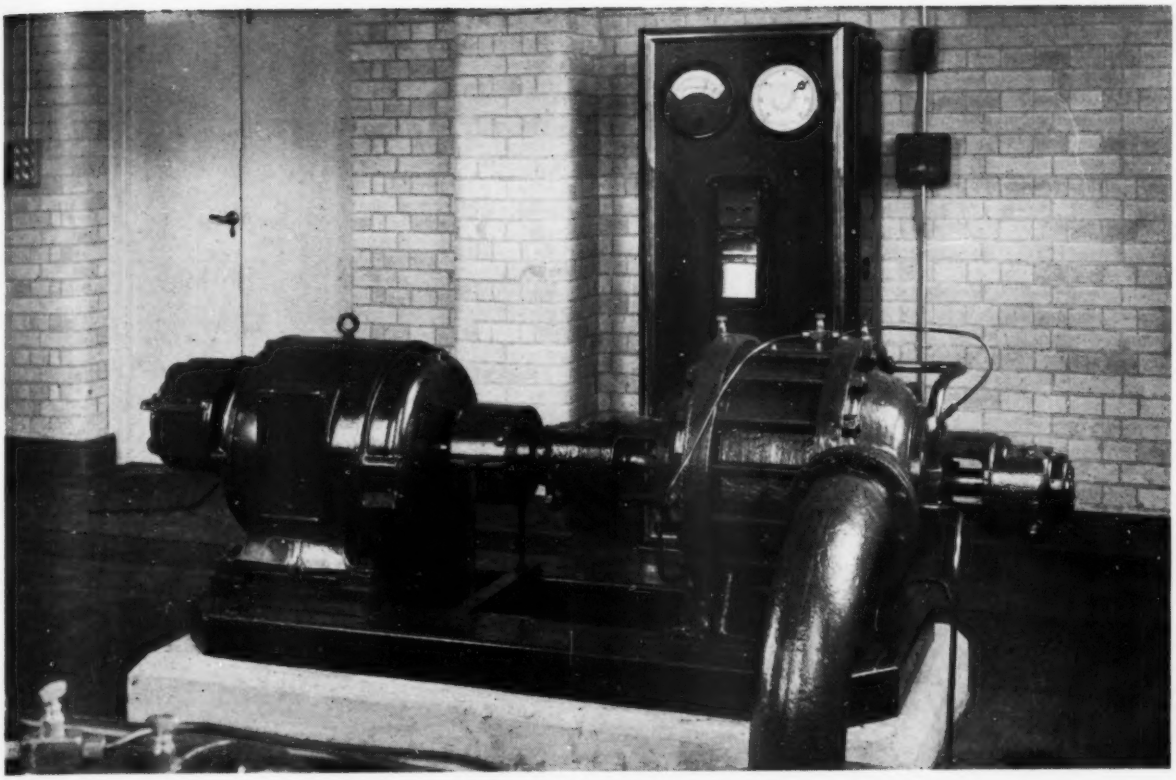

THE LEVEL BEST....

remote indication and control equipment by EVERSHED

Yet another example of the successful operation of Evershed remote indication and control equipment is the recent installation at the Thingoe Rural District Council's Rushbrooke Pumping Station.

A telemeter water level transmitter is installed at the water tower and is connected by a two wire Post Office telephone line to the Pumping Station some four miles away, where a cubicle housing the level indicator, graphic water level recorder and pump control relay is situated.

Adjustable high and low level contacts are provided on the pump control relay which operate an internally mounted power relay. The pump is thereby automatically controlled to maintain level in the water tower.

The pump feeding the water tower draws its supply from a surface tank where the level is maintained by " Noflote " Control apparatus. Supply of water to this surface tank is provided by a borehole pump which is also controlled by " Noflote " apparatus.

Full details of Telemeter and " Noflote " equipment are available in Publication WO.283 and WO.234.

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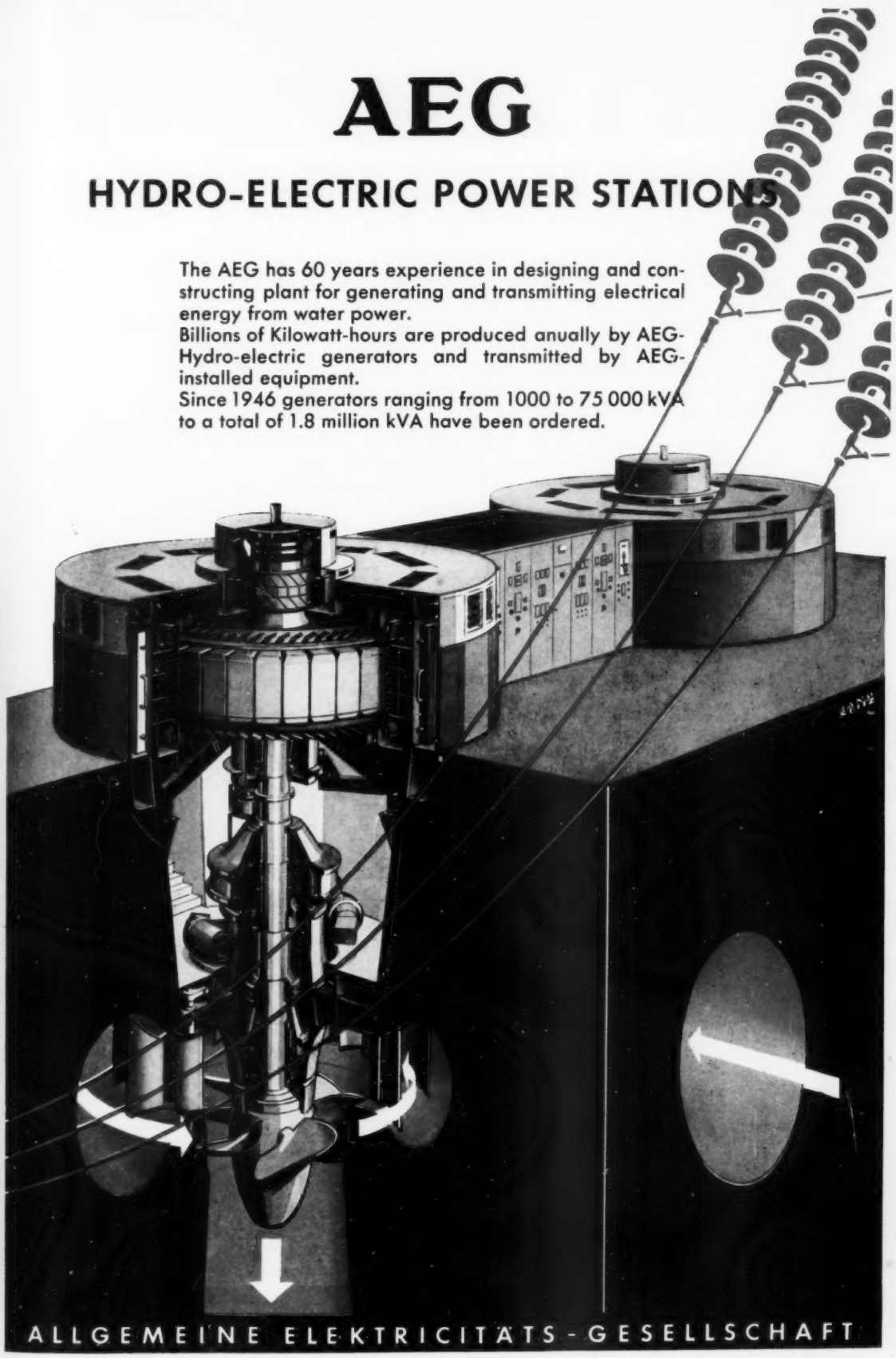

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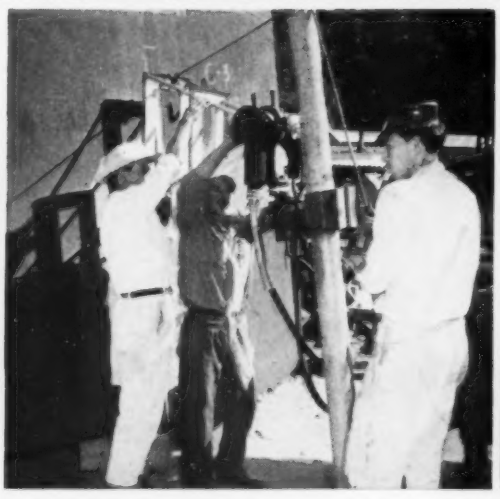
WELDING — Latest techniques are used for automatic and manual welding of penstock sections. A team of A. O. Smith specialists is available for complete inspection and supervision of welding on the job, anywhere in the world.



X-RAY INSPECTION — All welds are x-ray inspected for weak spots. In three miles of weld in the above installation, less than two percent required repair. Magnetic particle inspection also used. Here, too, A. O. Smith fieldmen can give on-the-job supervision.

MULTI-LAYER CONSTRUCTION — Walls are built-up from concentric layers of thin plate steel . . . progressively wrapped, tightened and welded around the inner shell to form a lighter but stronger penstock.

Penstocks save money on high-head jobs

Save up to 15% in weight of steel required for conventional single-wall penstocks . . . lower shipping and installation costs . . . eliminate costly stress-relieving of welds

ABOVE ground or under . . . A. O. Smith penstocks are the real answer to a lower cost high-head power plant.

Illustrated here are two power plants with A. O. Smith penstocks. More than 1300 ft. of penstock installed underground where the rock carries a portion of the load, and, *Multi-layer* penstocks, above-ground, provide water power for the famous Nilo Peçanha hydro-electric project of the Rio de Janeiro Tramway, Light & Power Co., Ltd.

As the name implies, *Multi-layer* construction consists of layers of thin plate steel of high tensile strength. Each layer is progressively wrapped around an inner core tightened and welded to form a lighter but stronger penstock.

This exclusive A. O. Smith design assures extra-strength . . . saves up to 15% in weight of steel as compared to conventional single-wall penstocks of same diameter. What's more, the safety factor is the same despite considerable reduction in weight. In addition, shipping and installation costs are less . . . costly stress-relieving of welds is eliminated. And, with *Multi-layer* design, there's no practical limitation to the pressures that can be handled.

If you want to save material, freight and cargo costs, erection and welding time, investigate *Multi-layer* penstock design. Take advantage of our unlimited research and production facilities for penstock construction. For more information on PENSTOCK design, write A. O. Smith Corporation, International Division, P.O. Box 2023, Milwaukee 1, Wisconsin, U.S.A.

MASSIVE WYES — At A. O. Smith, quality control never leaves the production floor. This giant "wye", for example, was hydrostatically tested at 1425 psi. Design is accurately verified by means of strain gauge and extensometer measurements.

Through research A.O. Smith *. . . a better way*

A.O.Smith
CORPORATION

INTERNATIONAL DIVISION
P. O. Box 2023
Milwaukee 1, Wisconsin, U.S.A.

719,000 kVA of FERRANTI Transformers for the Alcan Project

NEW CONTRACT

Ferranti Ltd. have been awarded a further order by the Aluminum Company of Canada Ltd., for 3-71,000 kVA, single phase Generator Transformers stepping up to 301,400 volts

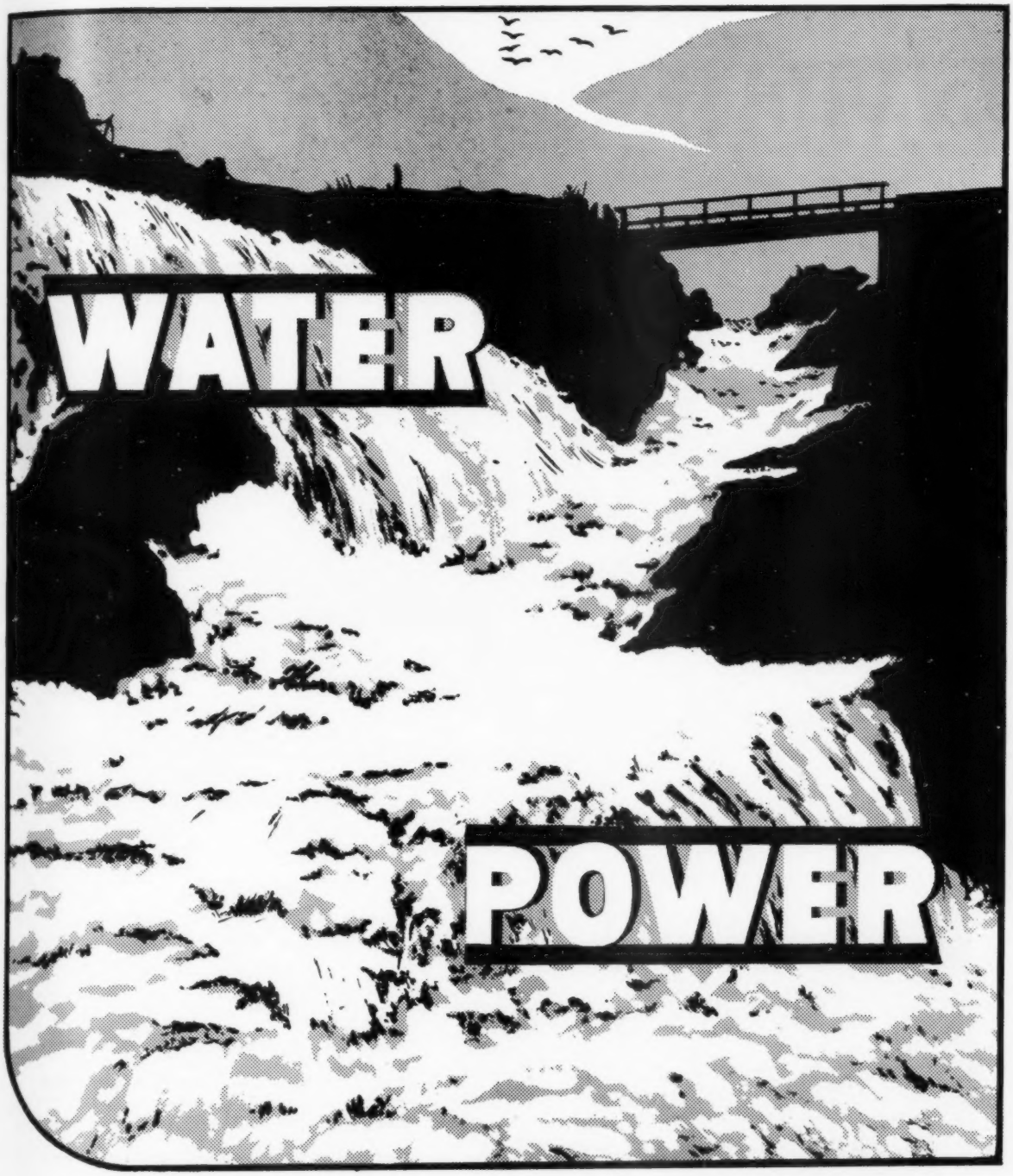
These units will form the second 213,000 kVA bank of generator transformers to be supplied by Ferranti Ltd., for installation in the now famous "Power Station inside a mountain" of the Alcan Project at Kemano, British Columbia. The transformers will have aluminium windings, and it is believed that they will form the largest bank of transformers with aluminium windings in the world. This order brings the total number of transformers supplied or under construction by Ferranti Ltd. for the Alcan Project to 13 units of a total capacity of 719,000 kVA, to the value of 1,210,000 dollars.

FERRANTI

FERRANTI LTD · HOLLINWOOD · LANCS

London Office: KERN HOUSE, 36 KINGSWAY, W.C.2

FT1772



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260 kV TRANSFORMERS

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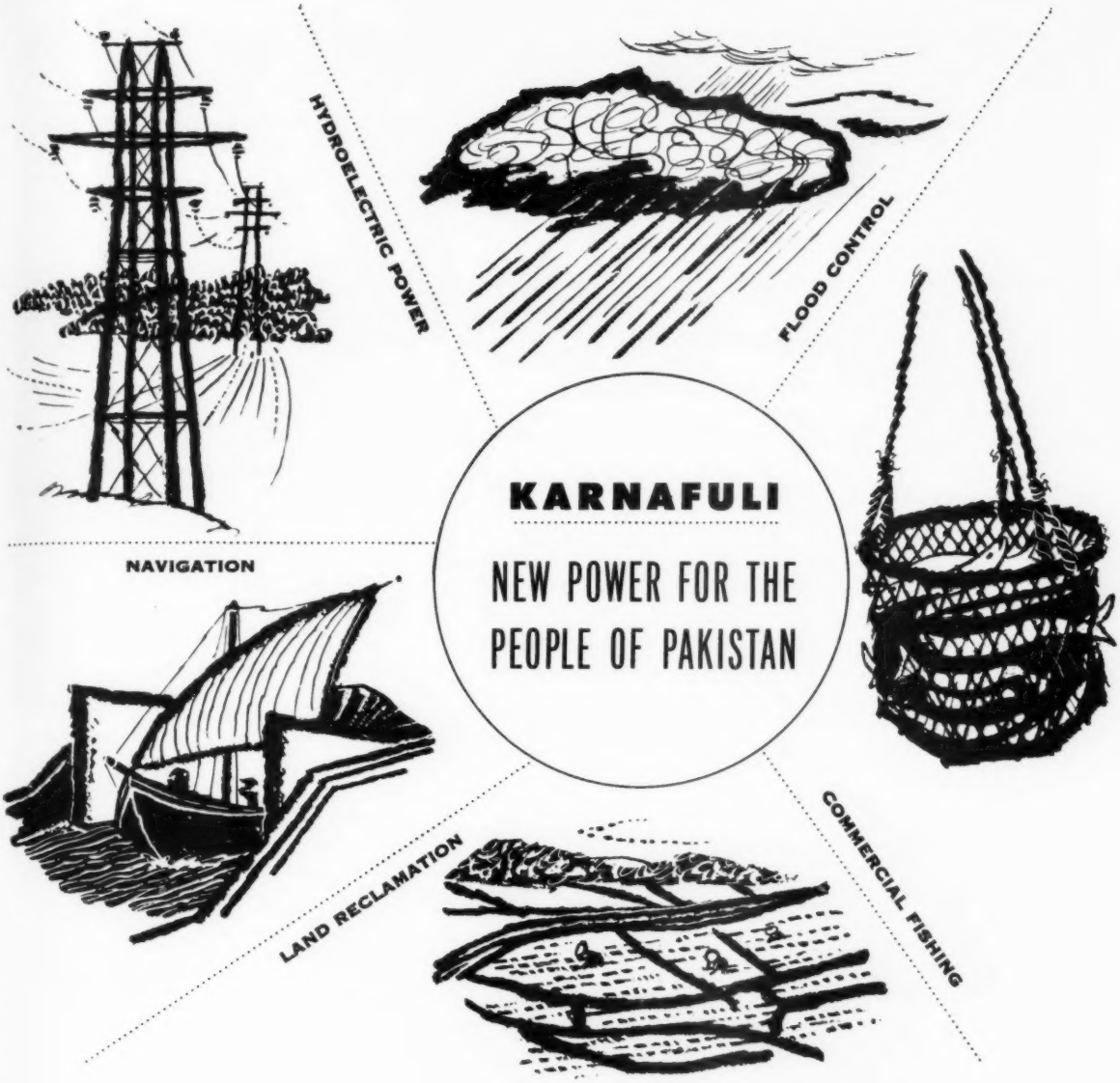
No. 7 Transformers for 50 MVA three-phase banks;

No. 6 Transformers for 75 MVA three-phase banks

Our range of production: Alternators - d. c. and a. c. motors – transformers with on load tap changing equipment – electromagnetic couplings – electric traction – metallic constructions – high pressure pipe lines – lifting equipments – crawler tractors – road rollers

SOC. NAZ. DELLE OFFICINE DI SAVIGLIANO — C. MORTARA 4-TORINO (ITALY)



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Now under construction, the Karnafuli Project marks an important forward step in the economic development of East Pakistan. Designed and engineered by the International Engineering Company, this multi-purpose dam and powerplant will ultimately generate 160,000 kw of hydroelectric power to meet vital industrial needs.

Effective flood control will benefit the entire Karnafuli River Basin area, also permitting reclamation of land for agriculture and other purposes. A system of locks will improve river navigation, aid in the extraction and shipping of forest products, create better facilities for commercial fishing. By 1960, estimated financial benefits from Karnafuli will total nearly 44 million rupees annually . . . over 50 million in 1965.

International Engineering has for years specialized in the design and engineering of water and power projects like Karnafuli. Their complete services — from preliminary survey to engineering supervision of construction — are available to governments and private industry worldwide.

INTERNATIONAL ENGINEERING COMPANY, INC.

74 New Montgomery Street • San Francisco, California, U. S. A.
A subsidiary of Morrison-Knudsen Company, Inc.

FULL INFORMATION about the International Engineering Company is contained in an illustrated 16-page brochure . . . write to Dept. C-2 for your copy today.

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DESIGNED, CONSTRUCTED AND ERECTED BY PIRELLI-GENERAL FOR I.C.I.

These straight line, terminal towers with switching structures, cables and accessories form part of a new 33 kV double circuit steel tower line erected for Imperial Chemical Industries Limited as an inter-connector between two of their works: 0.15 sq. in. steel cored aluminium conductors, manufactured by ourselves, were used on this line, which includes a river crossing.

Towers fabricated by Painter Bros. Ltd., of Hereford

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OVERHEAD LINES

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ASSOCIATED COMPANY OF THE GENERAL ELECTRIC CO LTD

FRANCIS–
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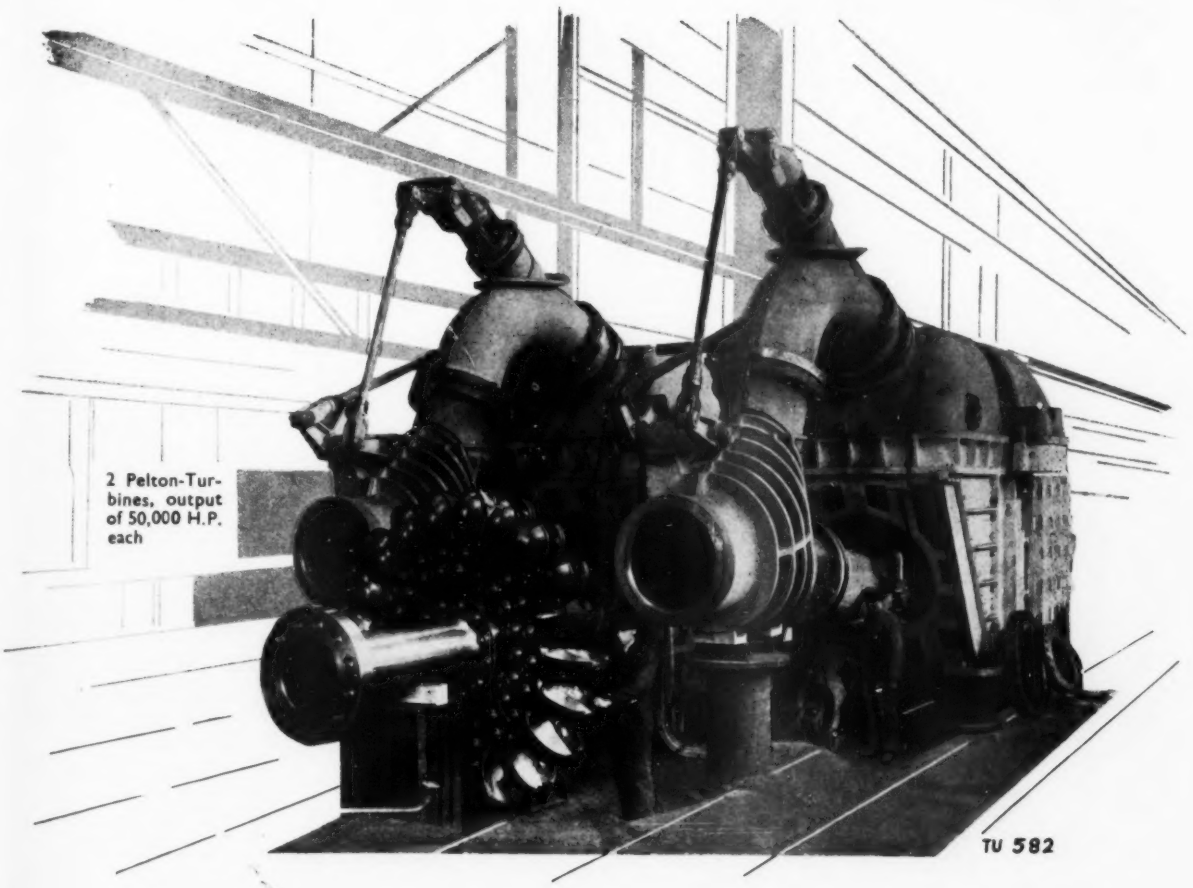
PELTON–
TURBINES

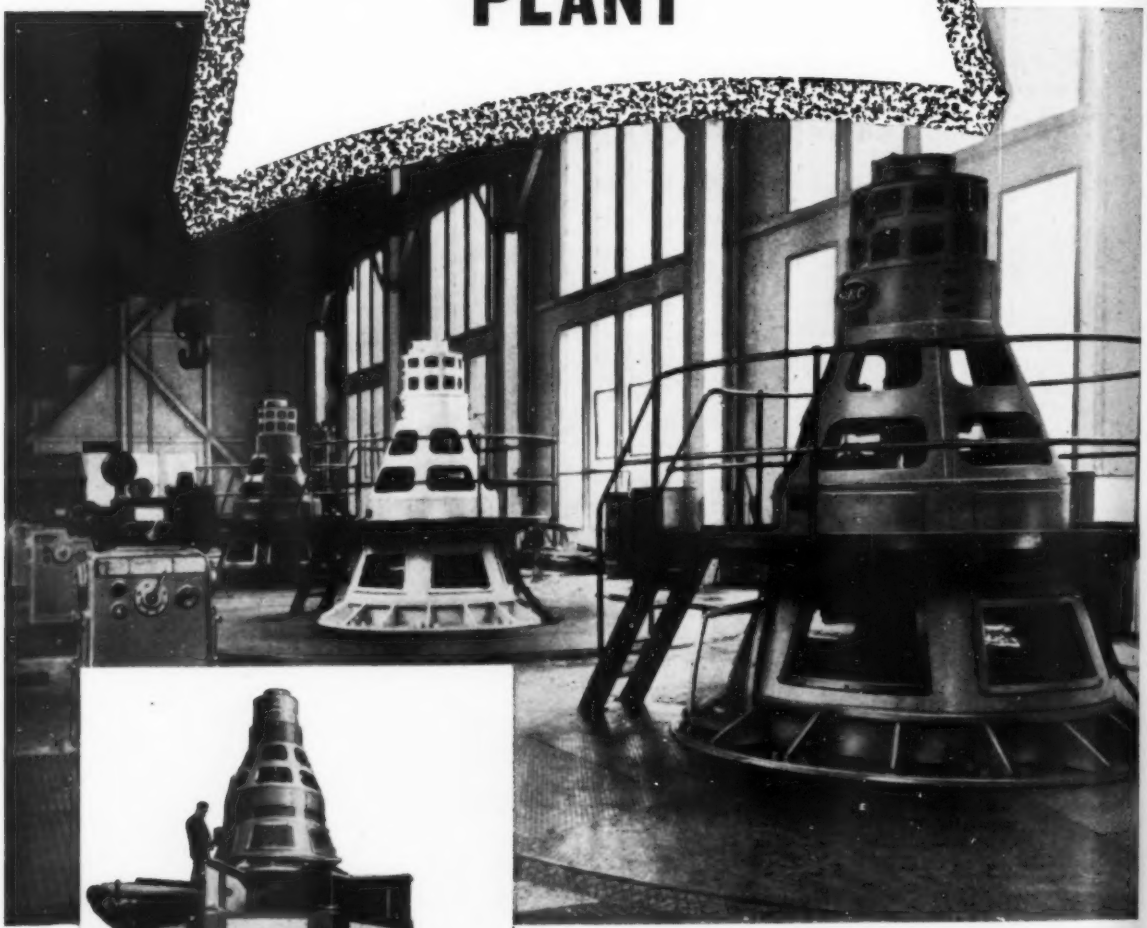
Automatic governors, closing devices



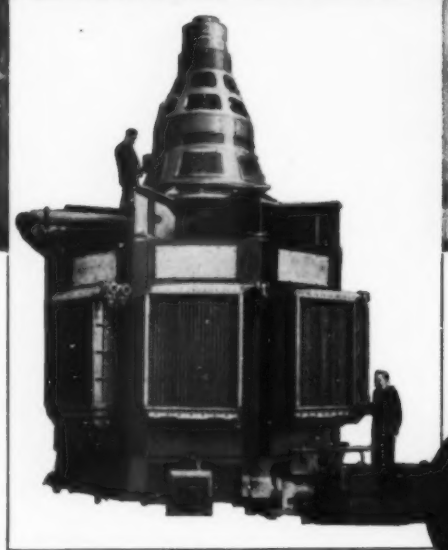
2 Pelton-Turbines, output of 50,000 H.P. each

—J. M. VOITH ST. POELTEN AUSTRIA

HYDRO-ELECTRIC PLANT



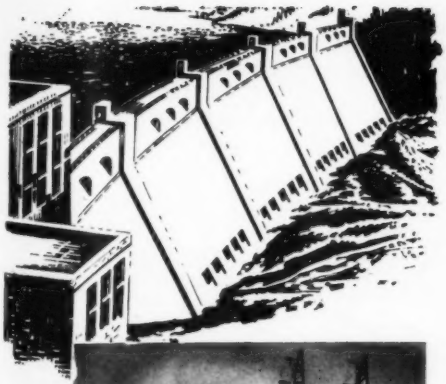
Three of five 25 MW, 11 kV., 600 r.p.m. sets in the Tungatinah Power Station, Tasmania.



One of the above alternators erected for test.

G.E.C.

THE GENERAL ELECTRIC CO. LTD., MAGNET HOUSE, KINGSWAY, LONDON, W.C.2



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Specially designed for the handling of materials on large-scale construction projects, HENDERSON Aerial Cableways are used in all parts of the world . . . they are found to move bigger loads faster and at lower cost. Low cost materials handling is the key to successful civil engineering undertakings—and wherever there is a dam or barrage, a bridge or viaduct to be built, a Henderson Cableway more often than not will be found to be the most practical means of construction.

FAST - RELIABLE - ECONOMICAL

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CABLEWAYS ARE ESSENTIAL ON ALL LARGE SCALE CONSTRUCTION PROJECTS

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THE MITCHELL CONSTRUCTION COMPANY

CIVIL ENGINEERING CONTRACTORS

a mile a month!

Over 6,000 ft. a month was the record breaking rate at
which tunnels were advanced by the Mitchell Construction Company
during the summer of last year on the contracts
they have for the North of Scotland Hydro-Electric Board at Breadalbane.
Such a rate of tunnel driving is believed to
be without parallel in this class of work anywhere in the world.
It has now been announced that the company have
established a world tunnelling record on these
contracts with a drive of 557 ft. on one heading in seven days.
Throughout the wide range of contracts upon
which they are engaged, similar progress is being maintained, indicative of
the careful planning and sustained sense of urgency which is given
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Consulting Engineers: Sir M. MacDonald and Partners

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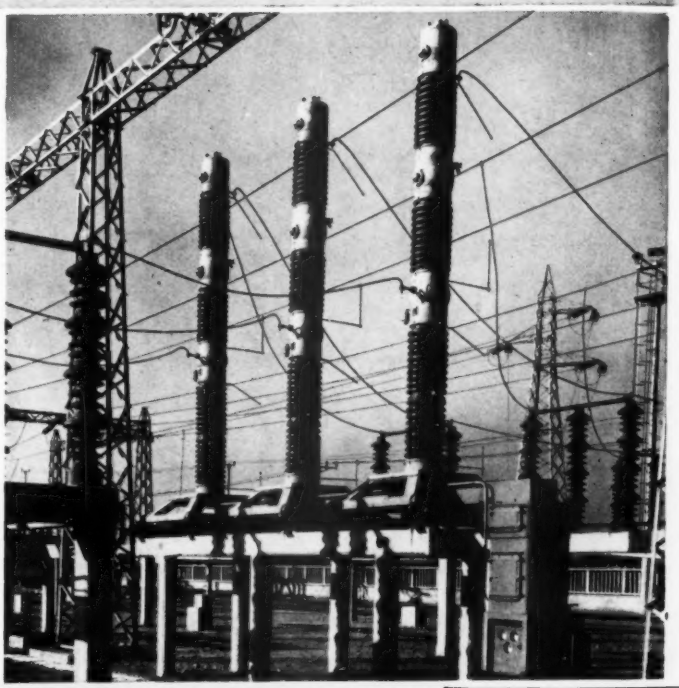
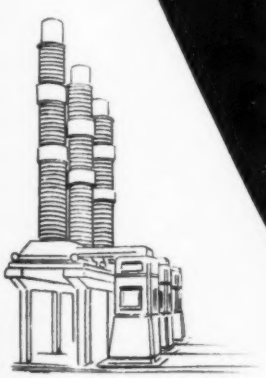


Type PO/350-N circuit breaker suitable for 150 kV, having 2200 MVA breaking capacity, installed at the Treviglio substation of the Italian State Railways, along the railway line from Milan to Venice.



Electrical switchgear for middle and high voltages, from 10 up to 220 kV indoor and outdoor installation

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HACKBRIDGE
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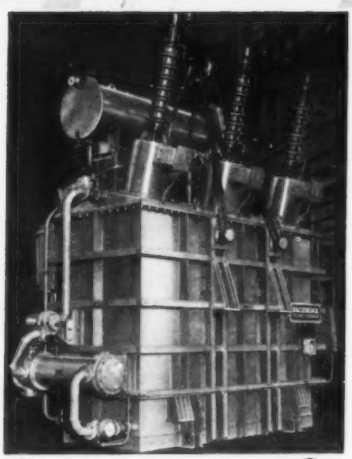

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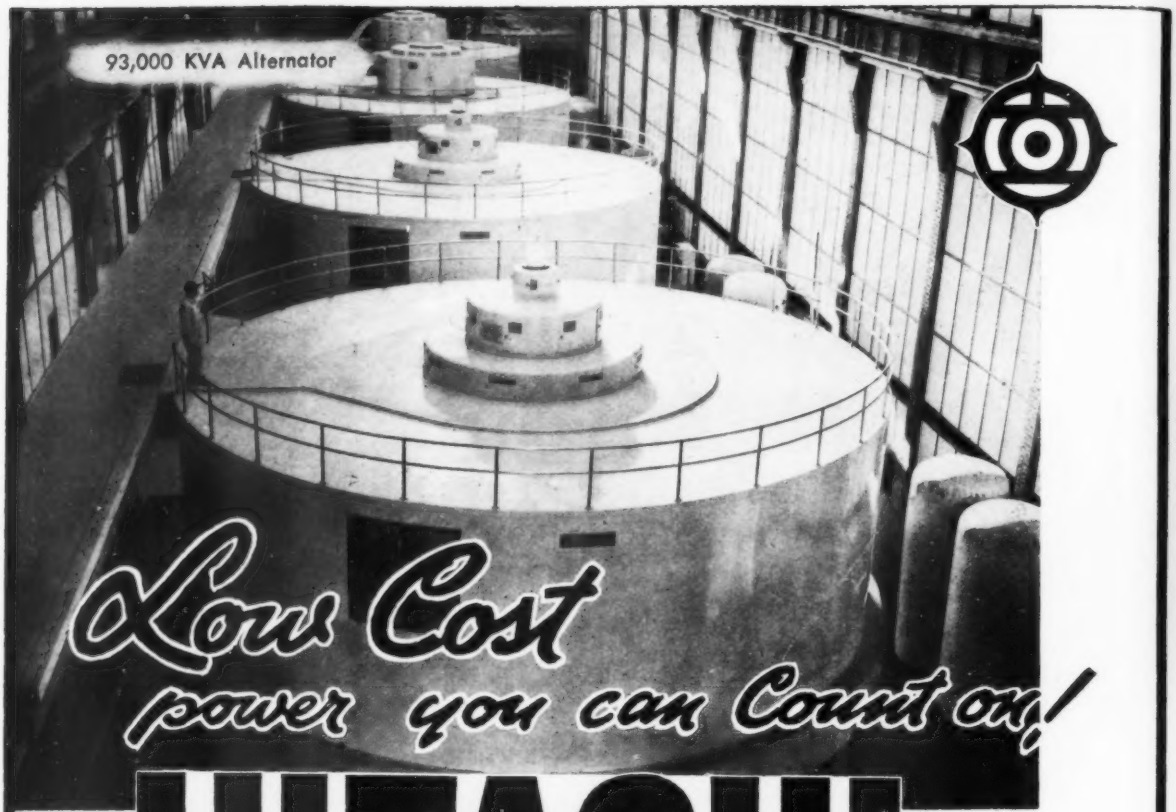
HYDRO - ELECTRIC STATION

Two Kaplan turbines, each designed for :

net head	12.10 m.
discharge	26 cu.m. per sec.
output	2,760 kW
speed	250 r.p.m.

Wheel completely assembled in workshop with blades set at maximum opening.



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WATERWHEEL GENERATORS

Hitachi's waterwheel driven alternators are backed with more than forty years of indefatigable research and engineering a experience. Several thousands of HITACHI alternators in wide variety of capacities have already been supplied with satisfactory results in power plants both at home and overseas.

Waterwheels	Boilers	Steam Turbines
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Hitachi, Ltd.

Tokyo Japan

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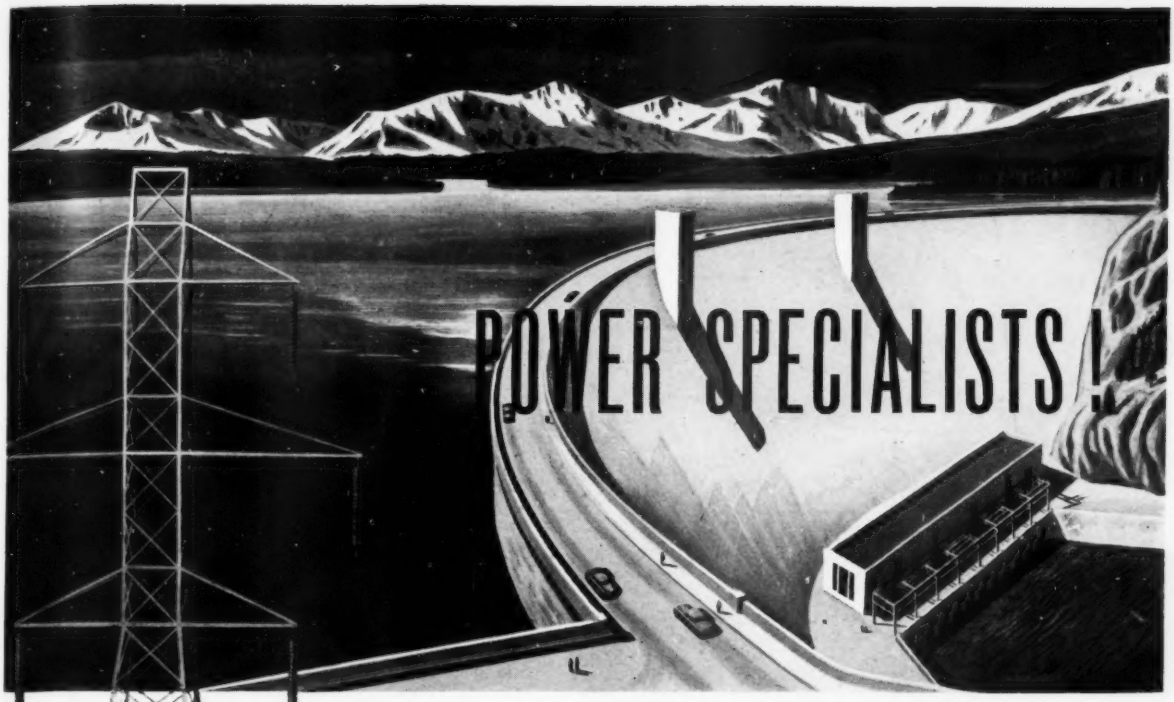

Kuljian has designed, engineered, and supervised construction of power plants the world over... with total electric generating capacity exceeding

2,000,000 KILOWATTS!

VAST power projects throughout the world—more than seventy in all—attest to The Kuljian Corporation's reputation as specialists in hydro-electric, steam, and diesel power plant design and construction. These plants represent a total generating capacity of over 2,000,000 kilowatts... a total investment of over half a billion dollars.

Behind every Kuljian project lie the combined skills and experience of a complete staff of internationally recognized experts in every phase of water resource development. No matter where *your* next project might be, The Kuljian Corporation is fully prepared to undertake efficiently all phases of design, engineering, and construction supervision to help bring about the quick, economical solution to your specific problem.

We invite your inquiry for detailed information.

SCOPE OF KULJIAN SERVICES

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engineers • constructors

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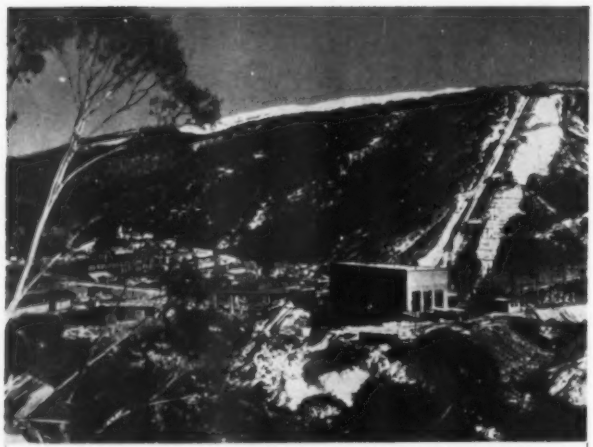
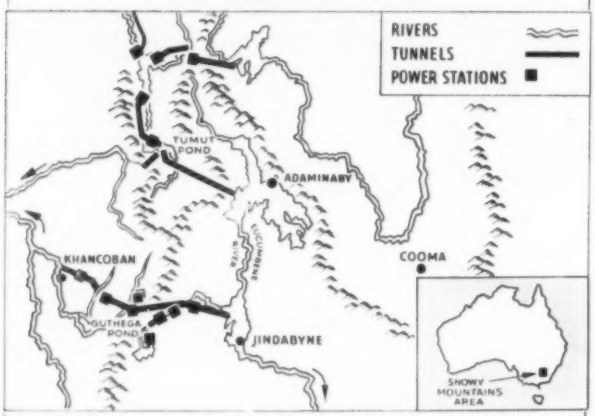
BRANCH OFFICES THROUGHOUT THE WORLD

ATLAS COPCO EQUIPMENT IN ACTION AS GIANT SNOWY MOUNTAINS SCHEME GETS UNDER WAY



Guthega power house near completion. It is providing the first water power from the Snowy Mountains scheme.



The scheme is one of the biggest power and irrigation projects ever undertaken in the world.

25 YEARS TO COMPLETE

The Australian Alps, south-west of Canberra, are the location of one of the biggest power and irrigation projects ever undertaken in the world. It is the Snowy Mountains scheme, expected to take 25 years and £A 422,000,000 to complete.

On the eastern slopes of the highest mountain in this 100-mile range, the Snowy River rises and then flows down to the south-east coast. Eventually this river will flow *westwards* to provide 2 million acre feet of water a year for irrigation and power stations with a total generating capacity of 3 million kilowatts.

85 MILES OF TUNNELLING

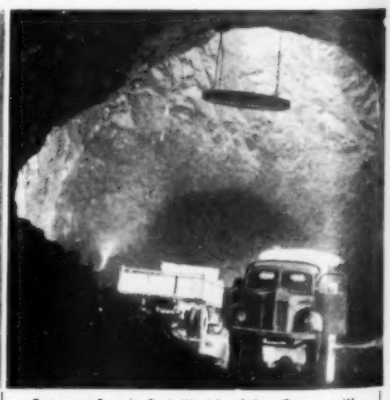
The Snowy Mountains scheme is engineering on a massive scale. It involves the construction of 7 major dams, 10 smaller ones, 85 miles of tunnels, 17 power stations (most of them underground), 400 miles of aqueducts, numerous shafts ranging up to 1,100 feet in depth, and hundreds of miles of mountain roads and access tracks. From the beginning, Atlas Copco rock drills, Atlas Copco air compressors and Sandvik Coromant drill steels are being widely used on many of these operations.

ATLAS COPCO PREPARE THE WAY

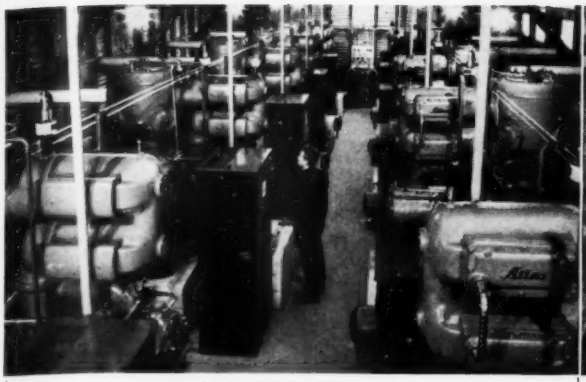
The first major stage of the scheme, the Guthega hydro-electric project consisting of a 100-ft. dam, a 3½-mile tunnel and a power station, has already been completed and is providing the first water power from the scheme. Atlas Copco rock drills fitted with Sandvik Coromant drill steels were chosen for the tunnels and all other rock excavations. This drilling unit was also at work building miles of mountain roads to prepare the way for the contractors, the Selmer Engineering Company of Norway.

Tunnelling at Adaminaby Dam diversion tunnel from jumbos, mobile drilling platforms pioneered by Atlas Copco.

Intake structure for the 3½-mile Guthega tunnel driven by Atlas Copco drills fitted with Sandvik Coromant steels.



Bottom of a shaft drilled by Atlas Copco drills and Sandvik Coromant steels on the Adaminaby diversion tunnel.



Battery of ten Atlas Copco AR 4E compressors installed at the junction shaft of the 14-mile Eucumbene-Tumut tunnel.

Atlas Copco drills fitted with Sandvik Coromant drill steels in action in the Guthega tunnel, the first major stage of the scheme.

BATTERY OF TEN ATLAS COPCO COMPRESSORS SUPPLY POWER FOR 14-MILE TUNNEL

Atlas Copco equipment is also in action on the second stage of the Snowy Mountains scheme. The main contractors are the American group Kaiser-Walsh-Perini-Raymond. On the Eucumbene-Tumut project Atlas Copco rock drills and Sandvik Coromant drill steels are widely used for various drilling operations, for example drilling a 4,000 feet access tunnel into the main tunnel. Here the rock drills are fed by Atlas Copco portable compressors. And at the main tunnel a battery of ten Atlas Copco AR4E compressors is the main power source for the drilling operations. A number of Atlas Copco AR3 compressors are also used by the Australian contractors, Allied Construction Pty. Ltd., on the diversion tunnel to Adaminaby Dam.

Over the past ten years, Atlas Copco light rock drills and Sandvik Coromant drill steels have become the world's most widely-used drilling combination. Both were developed together. Both are *working together;* turning projects like the Snowy Mountains scheme into reality all over the world.

From the start, Atlas Copco drilling equipment has been widely used on the Snowy Mountains scheme.

The services of the Project Department of Atlas Copco, whose job is to draw up drilling patterns and to advise on tunnelling and mining techniques, are at the disposal of contractors everywhere without obligation.

Drilling on the Guthega power station site with an Atlas Copco drill and Sandvik Coromant drill steels.

The Atlas Copco Group puts compressed air to work for the world. It embraces thirty-one Atlas Copco companies and twenty-four agents, manufacturing or selling and servicing Atlas Copco equipment in more than 50 countries throughout the world.

For further technical information about Atlas Copco Equipment write to the most convenient of the addresses given here:

UNITED KINGDOM, Atlas Copco (Great Britain) Ltd., Wembley, Middx.; FRANCE, Atlas Copco France S.A., 29, Rue Marbeuf, Paris 8e; HOLLAND, Atlas Copco Holland N.V., P.O. Box 6056, Rotterdam; ITALY, Atlas Copco Italia S.p.A., Viale Marche 15, Milan.
CANADA, Atlas Copco Canada Ltd., Montreal, AM.F., P.Q.; AUSTRALIA, Atlas Copco Australia Pty. Ltd., P.O. Box 54, Auburn, N.S.W.; SOUTH AFRICA, Delfos & Atlas Copco (Pty) Ltd., P.O. Box 504, Benoni, Transvaal; U.S.A., Atlas Copco Pacific, Inc., 930 Brittan Avenue, San Carlos, California; Atlas Copco Eastern, Inc., P.O. Box 2568, Paterson 2, N.J.

Readers in countries outside those listed above and who do not know the name of their local Atlas Copco company or agent, please write to Atlas Copco AB, Stockholm 1, Sweden.

THE ATLAS COPCO GROUP OF COMPANIES

Manufacturers of Stationary and Portable Compressors, Rock-Drilling Equipment, Loaders, Pneumatic Tools and Paint-Spraying Equipment

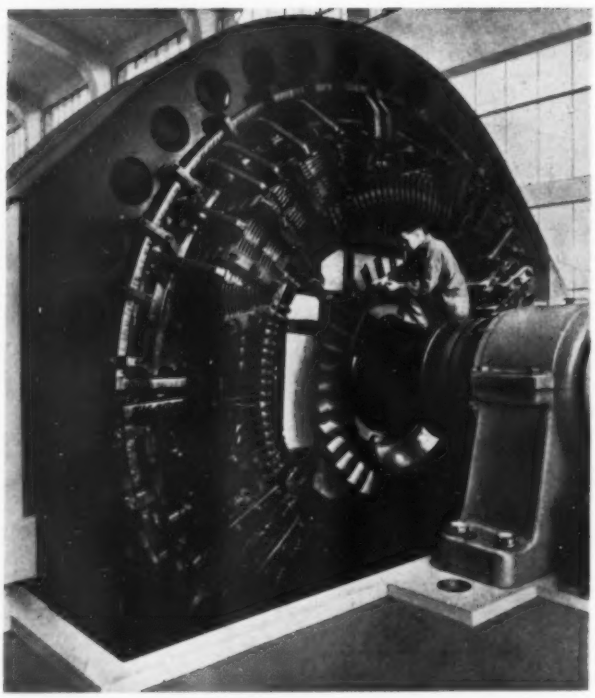
MADE IN AUSTRIA

this is

the Semmering, a 4,500 ft. mountain, 60 miles south of Vienna, which was crossed by the first mountain railway in the world as early as 1854. Electrification of this line will soon be completed.

Photo: Walden

ELIN



...and that is

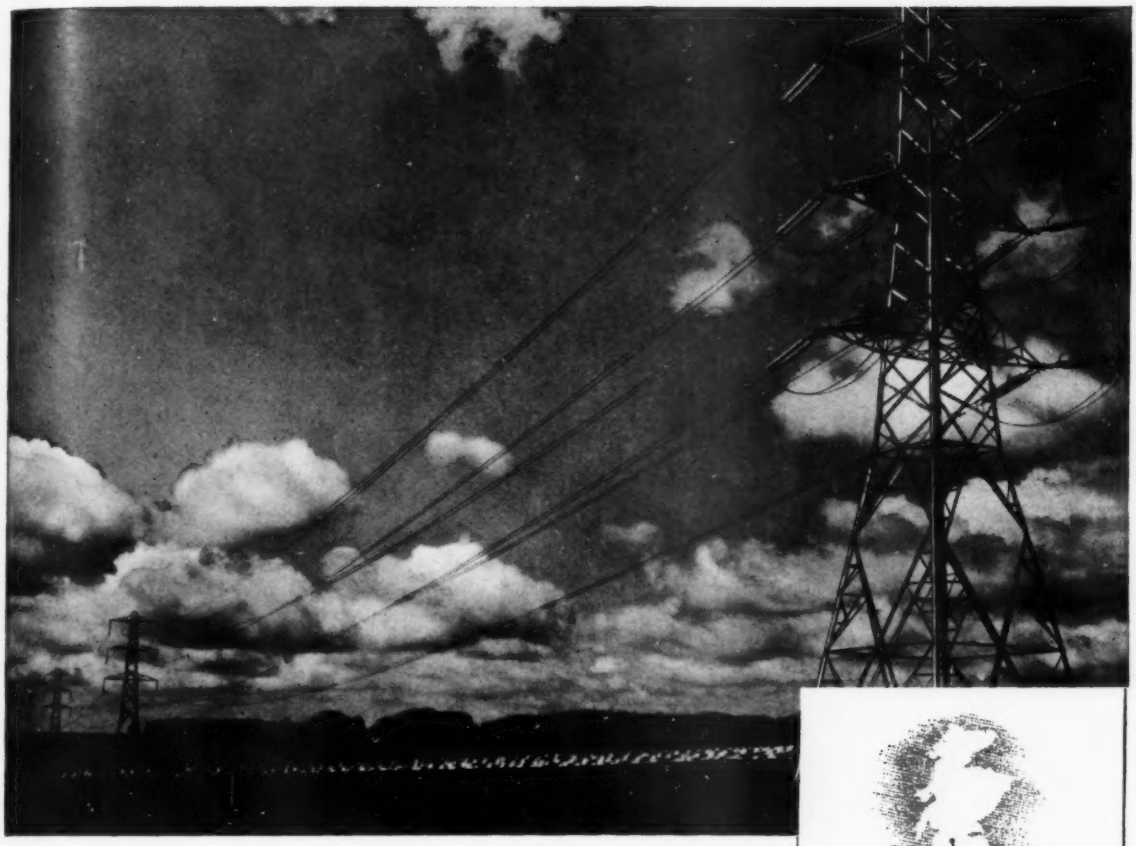
one of the large single-phase alternators, 23 MVA at 500 r.p.m. and 16 2/3 c.p.s., recently installed in a Vienna traction substation for supplying traction power to the Semmering line.

Photo: ELIN

"ELIN"
VIENNA AUSTRIA

AKTIENGESELLSCHAFT FÜR
ELEKTRISCHE INDUSTRIE

Power strides trouble-free across Britain



Sections of the 275kV Supergrid for which "Armourlight" Toughened Glass Insulators are being supplied.

For their 275 kV Supergrid, the Central Electricity Authority is using chiefly "ARMOURLIGHT" Toughened Glass Insulators. Their high electrical and mechanical strength means trouble-free operation. Over 550,000 "ARMOURLIGHT" Insulators are being supplied for this great project—they are helping to extend a network of high voltage lines from Clydeside to the Thames. "ARMOURLIGHT" Toughened Glass Insulators have a high resistance to power arcs and are unpuncturable by lightning surges. Their special glass construction enables a damaged unit to be detected by quick visual inspection from the ground. Leading Electrical Authorities throughout the world are using ever-increasing quantities of "ARMOURLIGHT" Toughened Glass Insulators.

For technical advice and literature, write to Pilkington Brothers Limited, Insulator Sales Department, Ravenhead Works, St. Helens, Lancs.

"ARMOURLIGHT" HIGH VOLTAGE TOUGHENED GLASS INSULATORS

PILKINGTON BROTHERS LIMITED

ST. HELENS, LANCS. (TEL: ST. HELENS 4001) OR SELWYN HOUSE, CLEVELAND ROW, ST. JAMES'S, LONDON, S.W.1 (TEL: WHITEHALL 5672-6) 'ARMOURLIGHT' is a registered trade mark of Pilkington Brothers Limited H.V.I.5.

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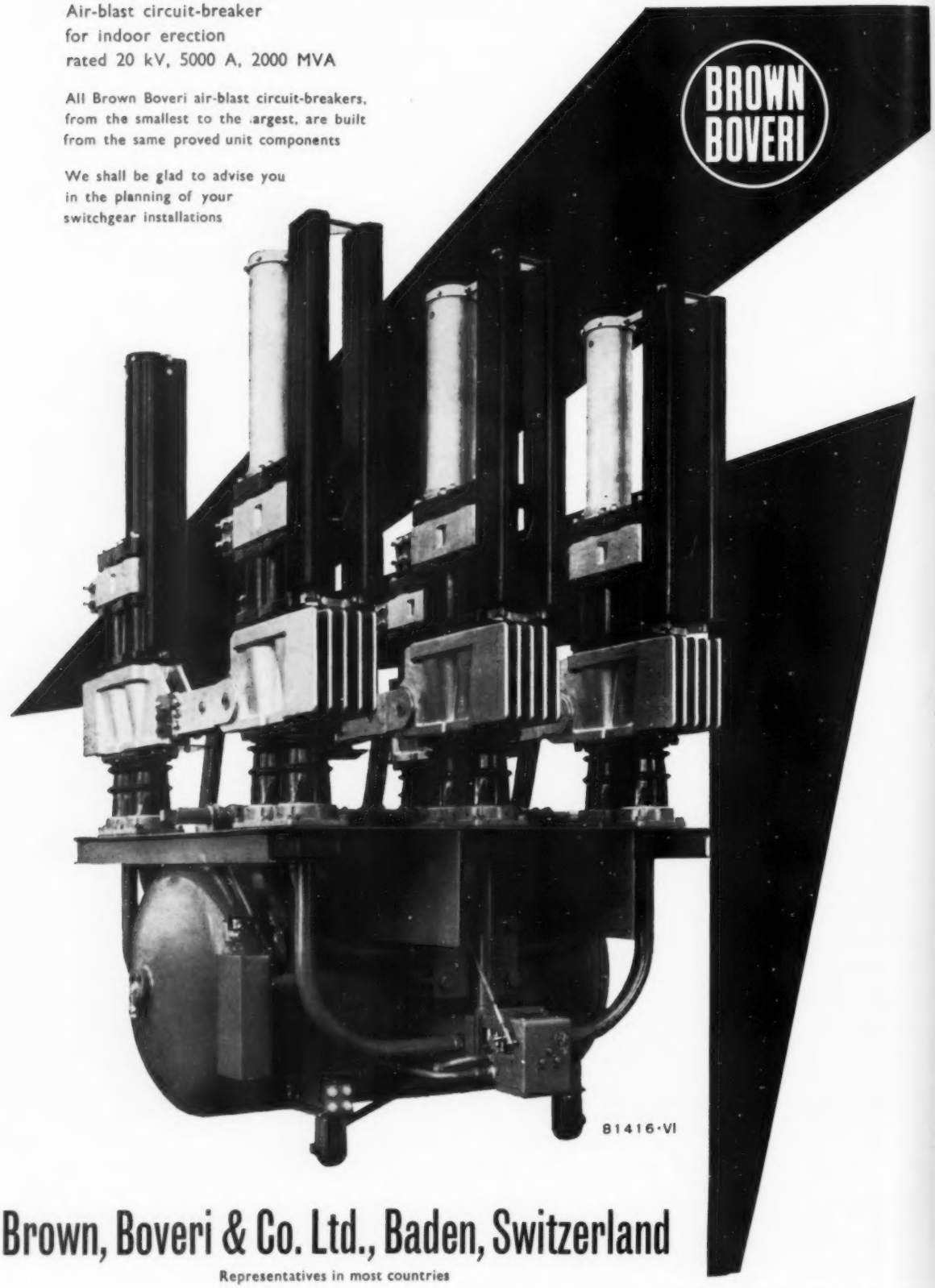
Air-blast circuit-breaker
for indoor erection
rated 20 kV, 5000 A, 2000 MVA

All Brown Boveri air-blast circuit-breakers, from the smallest to the largest, are built from the same proved unit components

We shall be glad to advise you in the planning of your switchgear installations

BROWN BOVERI



Brown, Boveri & Co. Ltd., Baden, Switzerland

Representatives in most countries

CLUTHA DIVERTED BEFORE ZERO

The Clutha River was turned into its new course through the diversion channel of the Roxburgh hydro-electric project at 6.10 a.m. yesterday, 18 hours after the first rubble had been pushed into the stream, and six hours ahead of schedule.

Yet at 9 p.m. the day the work began, the whole operation was nearly abandoned because of a rising river and discouraging weather reports.

THIS HIGH-LEVEL DRAMA WAS ENACTED WHILE THE BULLDOZER TEAM WAS STILL STRUGGLING TO DEFEAT THE RISING WATERS

victory over time and flood

Eleven Caterpillar Tractors with Birtley bulldozers fought unceasingly against the rising flood of New Zealand's great Otago River and beat the time schedule by 6 hours "None . . . . . faltered for one moment", announced the contractors. Triumphant proof indeed of the thorough reliability of Birtley Caterpillar Equipment.

you can rely on

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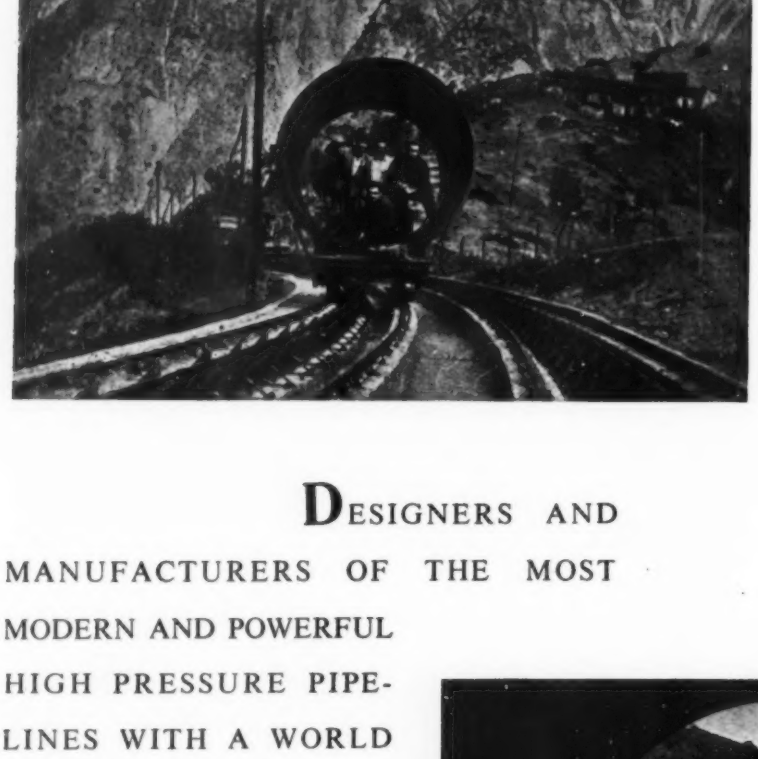

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Diameter—2·50-2·20-2·00 metres

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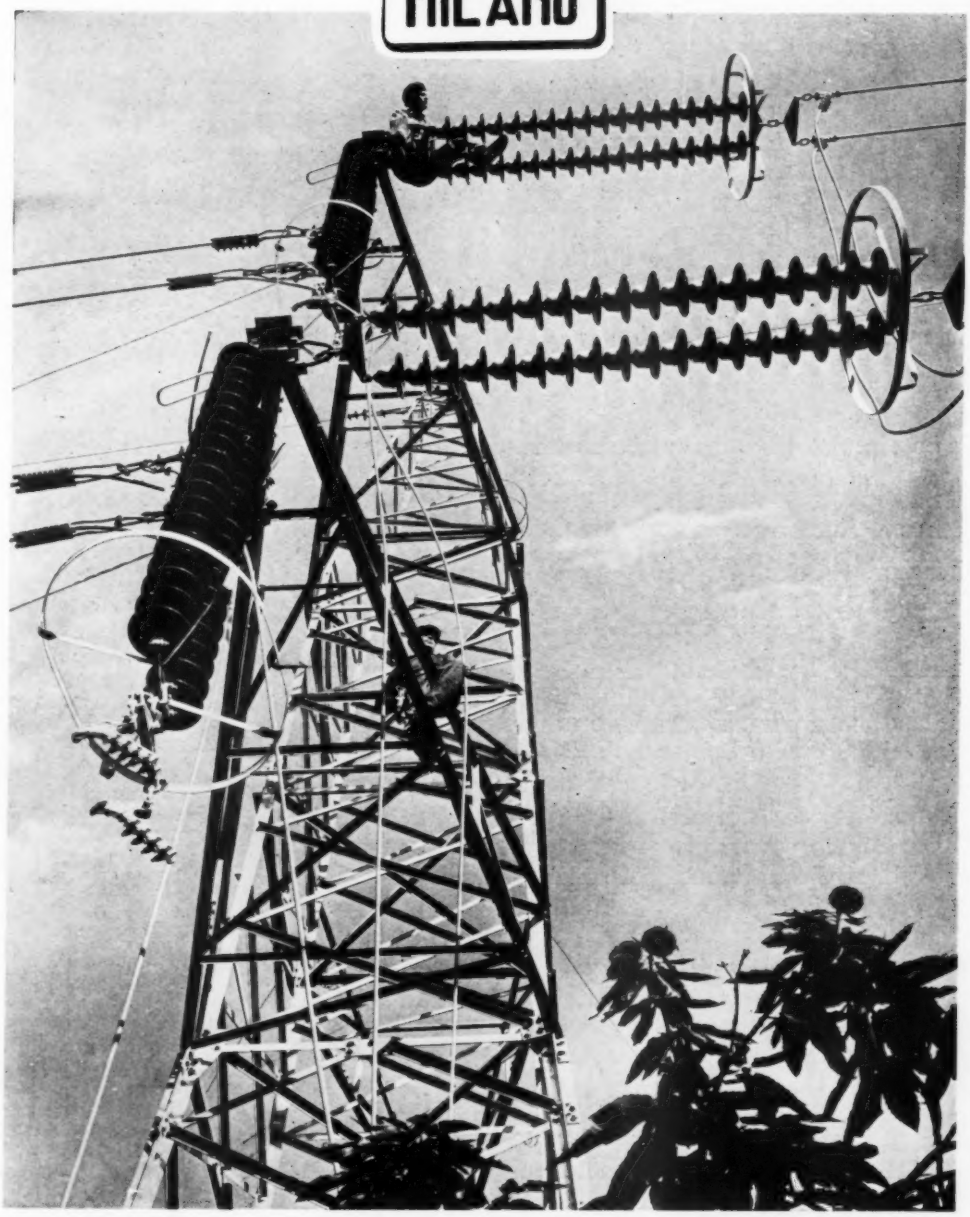
HIGH VOLTAGE SALVI IFI MILANO LINE FITTINGS



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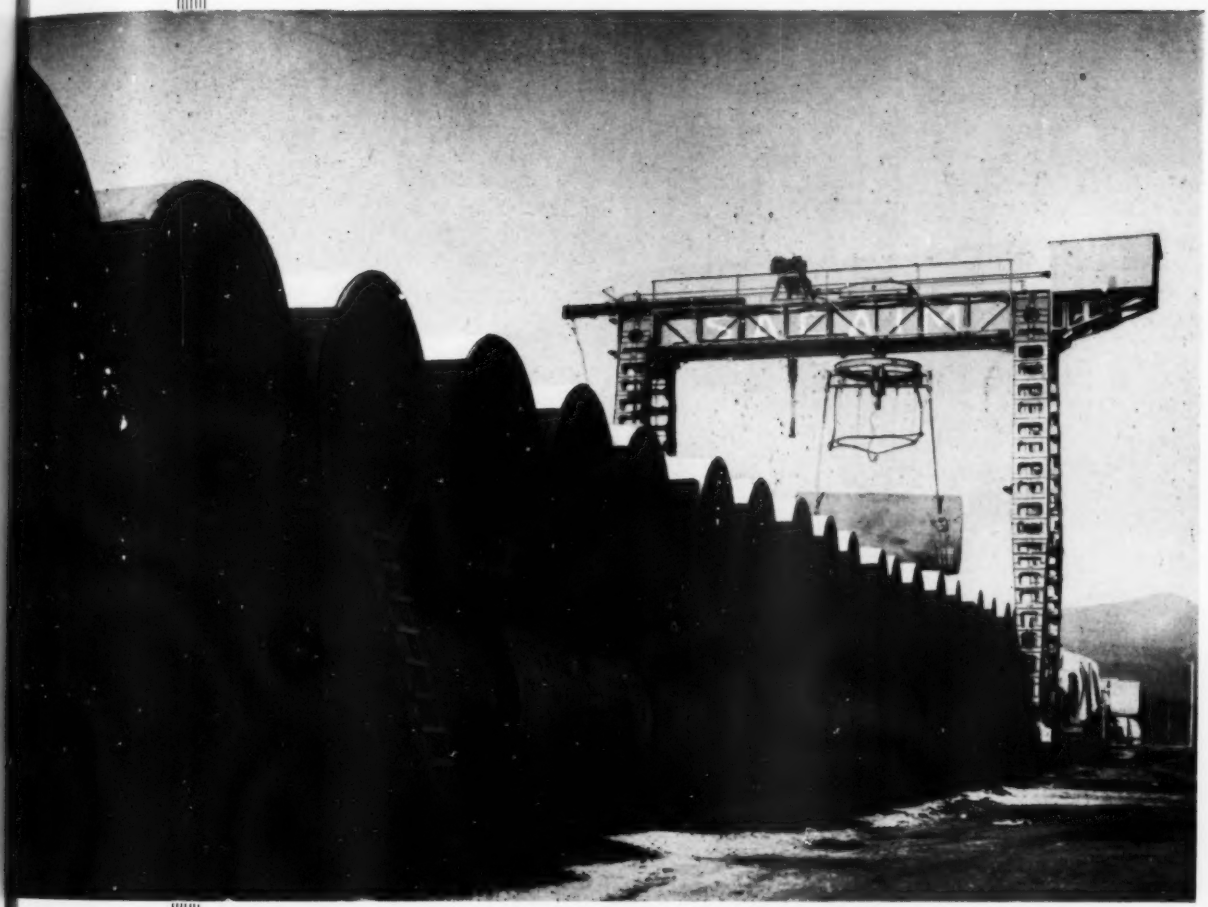
Height of post 116"
Cantilever strength 2,000 lb.
Dry withstand test 580 K.V.
Wet withstand test 520 K.V.

Prestressed reinforced concrete penstocks of any diameter and pressure



Main penstock of prestressed reinforced concrete (diameter 6 ft. 7 ins., operating at 440 lb. per sq. in.) made for the Maè-Piave Hydro-Electric station of
S.A.D.E. - SOC. ADRIATICA DI ELETTRICITA'

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Soc. p. Az. Cementi Armati Ing. Mantelli

VENICE (ITALY) - Accademia 979/A - Telephone 24.072

The Kaplan turbines installed at the Birsfelden Power Station, which are amongst the largest in Europe, each have a maximum output of 30,000 HP. The two Escher Wyss units are designed for the following data :

Head	4.06—9.45 metres
Quantity of water	300 cub.m/sec
External runner diam.	7.2 metres
Hydraulic pressure on each of the 4 blades	100 tons
Centrifugal force of 1 blade at 68.2 rpm	120 tons

ESCHER WYSS Ltd.,
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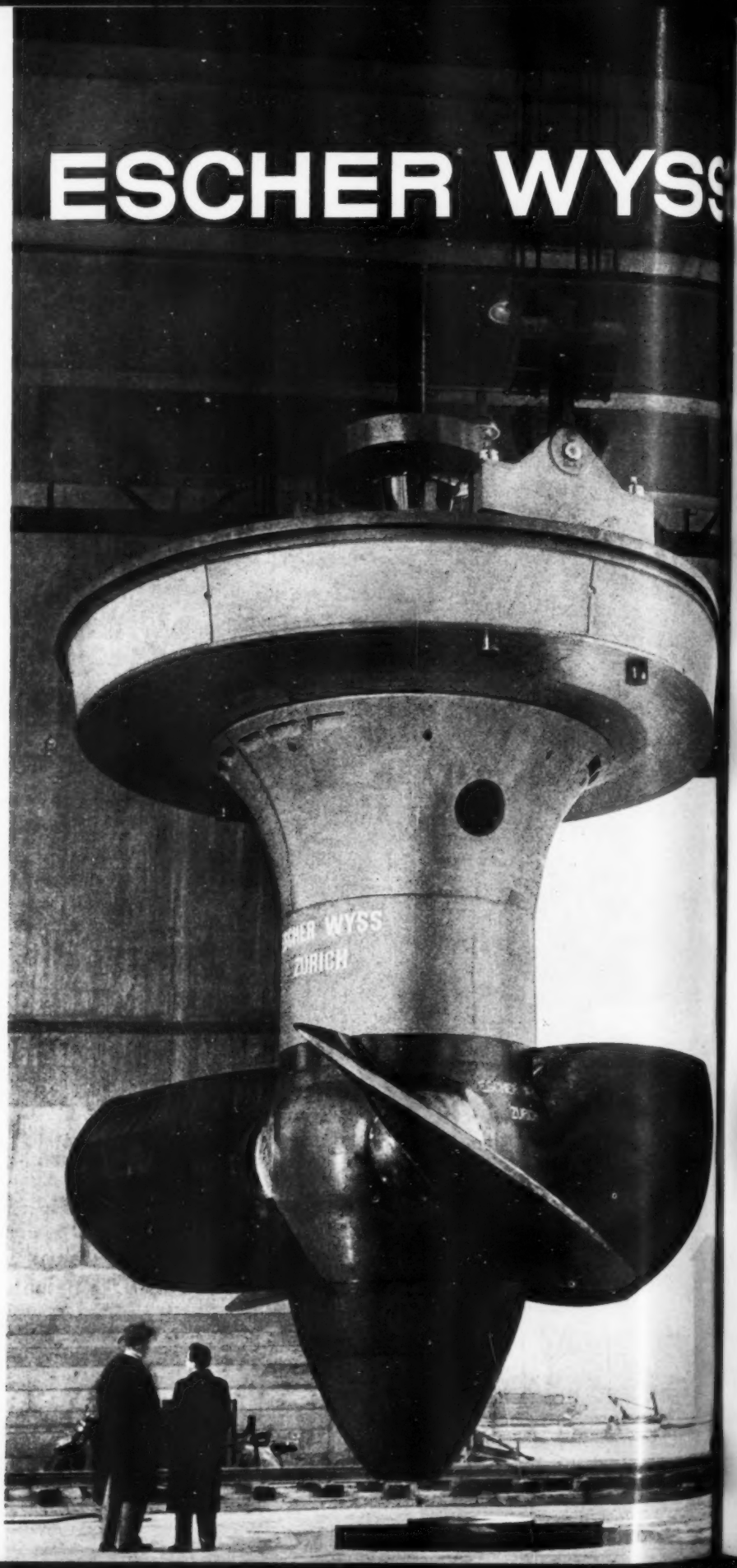
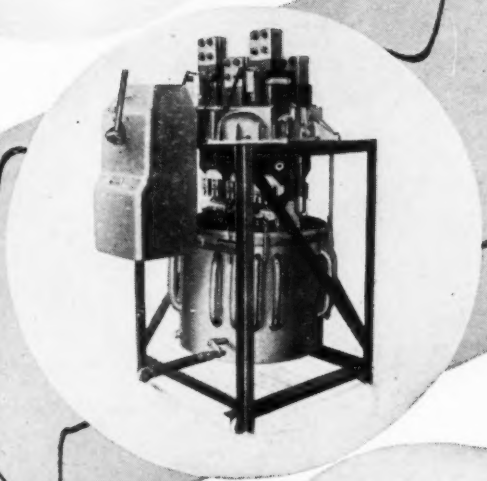


Interruttori . . Circuit Breakers

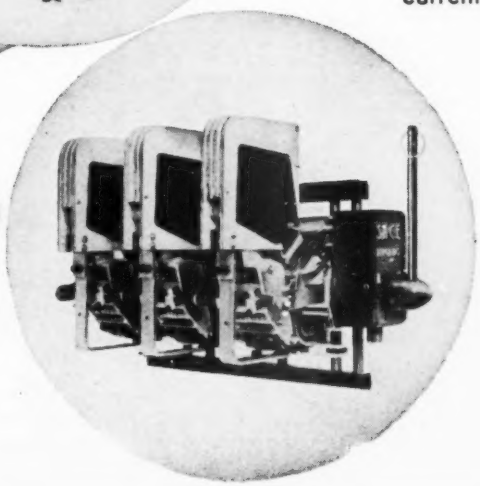
. . . small oil volume type
voltages up to 35 kV
currents up to 800 A

. . . ad olio ridotto
tensioni fino a 35 kV
correnti fino a 800 A



. . . in cassa d'olio
tensioni fino a 35 kV
correnti fino a 12 000 A

. . . oil tank type
voltages up to 35 kV
currents up to 12 000 A .



. . . in aria
tensioni fino a 600 V
correnti fino a 4 000 A

. . . air type
voltages up to 600 V
currents up to 4 000 A

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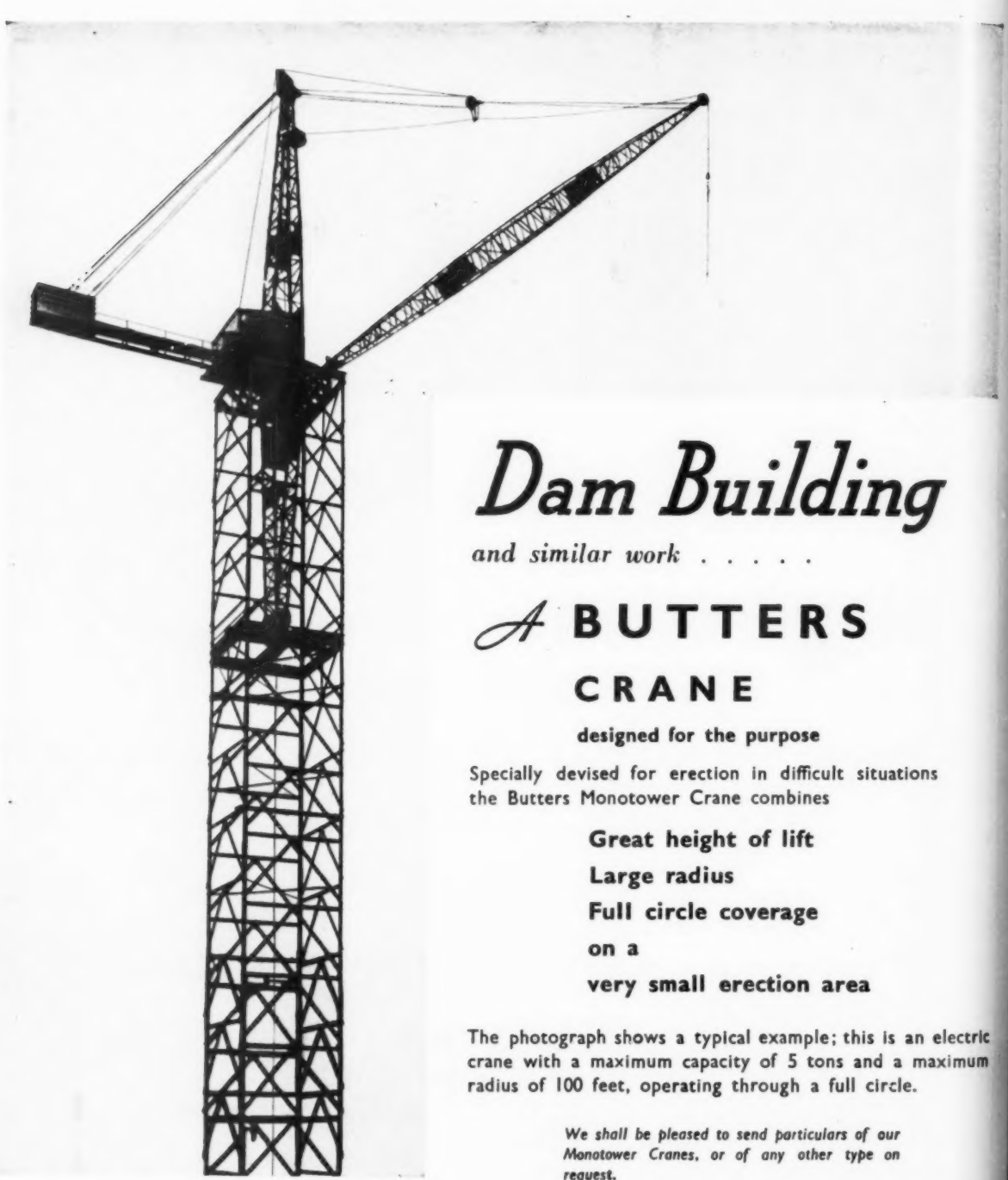

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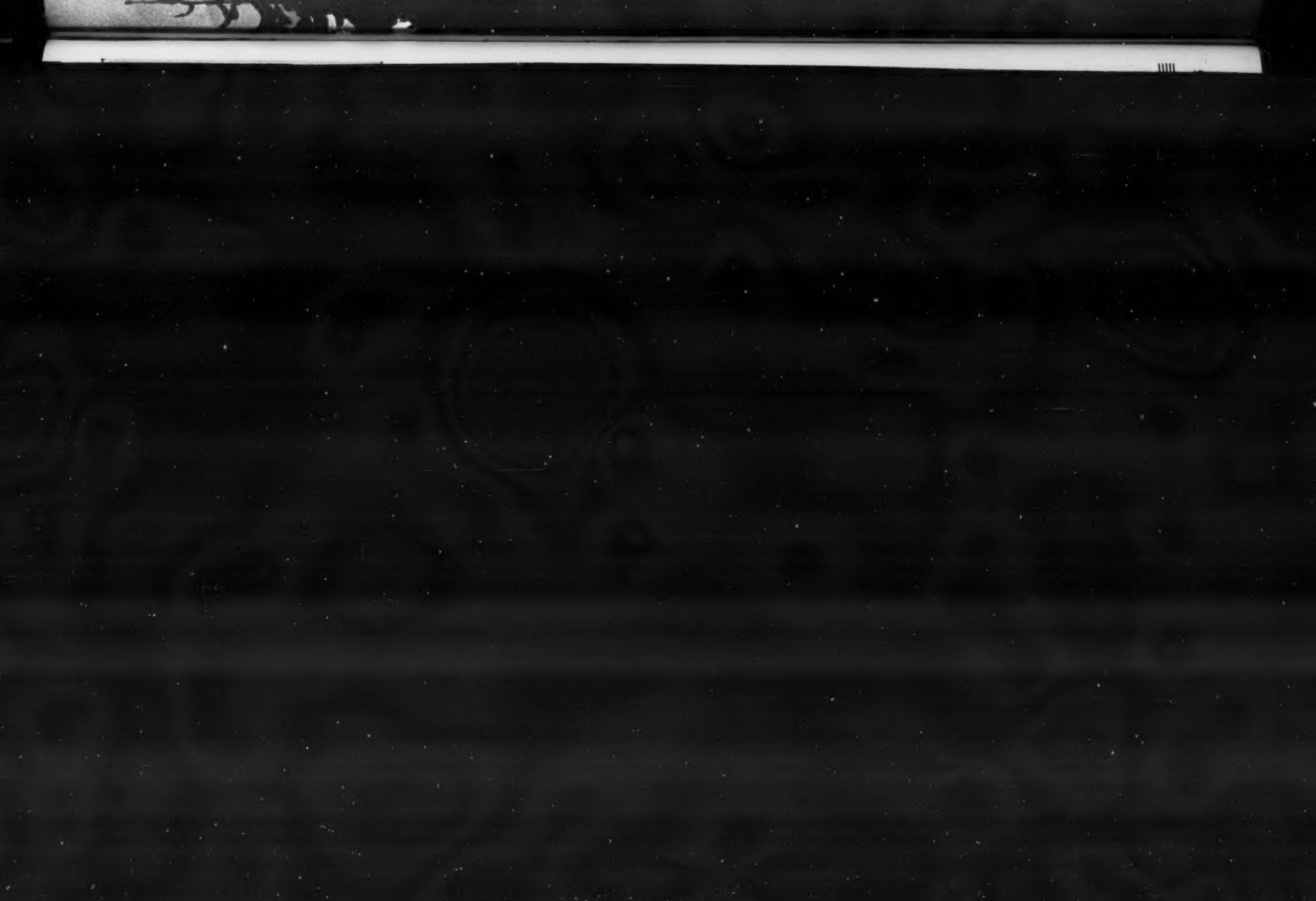

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The picture shows an eight-blade runner of a Kaplan turbine 68,000 HP, head 56 m., 250 r.p.m.

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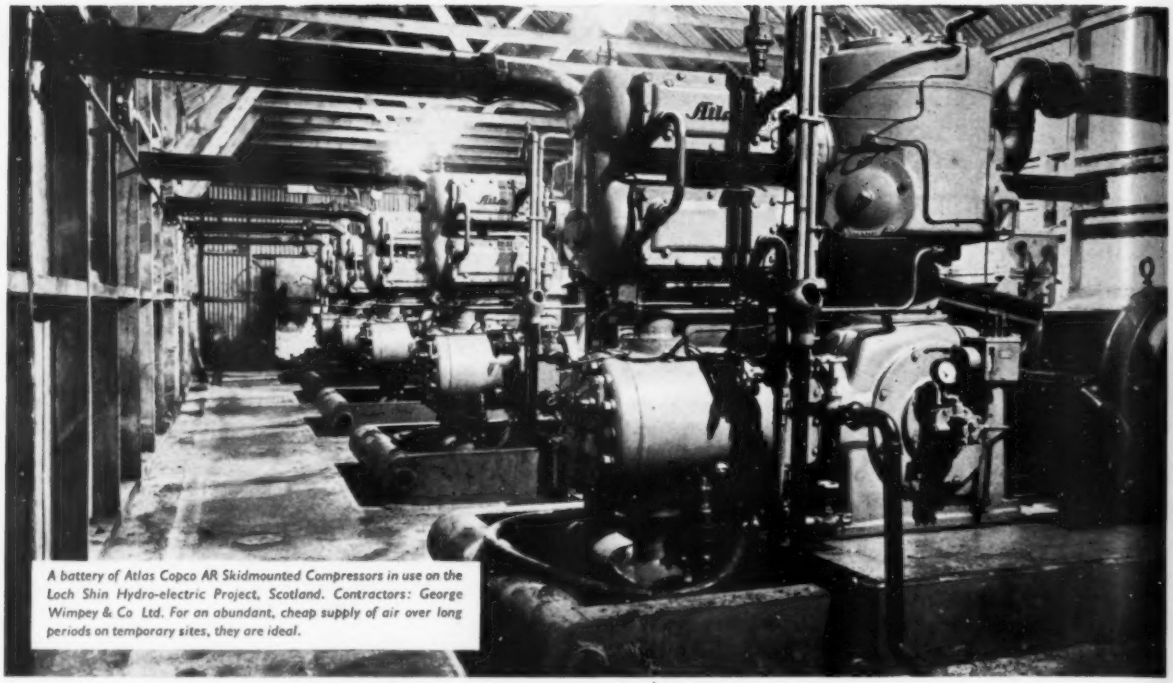


A battery of Atlas Copco AR Skidmounted Compressors in use on the Loch Shin Hydro-electric Project, Scotland. Contractors: George Wimpey & Co Ltd. For an abundant, cheap supply of air over long periods on temporary sites, they are ideal.

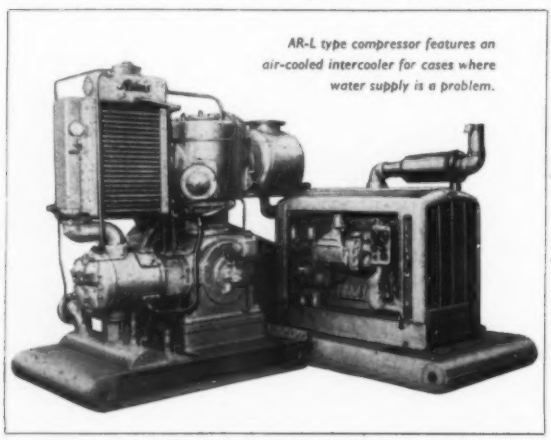
Why Contractors choose Atlas Copco AR Skidmounted Compressors—*instead of large portables*

THEY SAVE POWER COSTS

The power consumption of the AR series of Atlas Copco compressors is less than 20 h.p. units per 100 cu. ft./min. at 100 lbs. per sq. in. This compares with 21-22 h.p. units for other types of stationary compressors of comparable size and more than 25 h.p. units for portable compressors.

THEY CUT INSTALLATION COSTS

Thanks to their well-balanced design, these compressors can be mounted on fabricated steel skid frames and can therefore be run on bare ground without concrete foundations or bolting down. Atlas Copco AR skidmounted compressors *combine the mobility of portables with the performance and economy of stationary compressors.*



AR-L type compressor features an air-cooled intercooler for cases where water supply is a problem.

THEY ARE INDEPENDENT OF COOLING WATER

As an extra feature, the compressors can now be supplied as radiator-cooled, self-contained units (see photograph below).

THEY USE ELECTRIC OR DIESEL DRIVE

Electric drive gives low maintenance and operating costs. Where electric power is not available, diesel engines can be used.

The Atlas Copco Group puts compressed air to work for the world. It embraces thirty-one Atlas Copco companies and twenty-four agents, manufacturing or selling and servicing Atlas Copco equipment in more than 50 countries throughout the world.

For further technical information about Atlas Copco AR Skidmounted Compressors write to the most convenient of the addresses given here:

UNITED KINGDOM, Atlas Copco (Great Britain) Ltd., Wembley, Middx.; FRANCE, Atlas Copco France S.A., 29, Rue Marbeuf, Paris 8e; HOLLAND, Atlas Copco Holland N.V., P.O. Box 6056, Rotterdam; ITALY, Atlas Copco Italia S.p.A., Viale Marche 15, Milan.

CANADA, Atlas Copco Canada Ltd., Montreal, A.M.F., P.Q.; AUSTRALIA, Atlas Copco Australia Pty. Ltd., P.O. Box 54, Auburn, N.S.W.; SOUTH AFRICA, Delfos & Atlas Copco (Pty.) Ltd., P.O. Box 504, Benoni, Transvaal; U.S.A., Atlas Copco Pacific, Inc., 930 Brittan Avenue, San Carlos, California; Atlas Copco Eastern, Inc., P.O. Box 2568, Paterson 2, N.J.

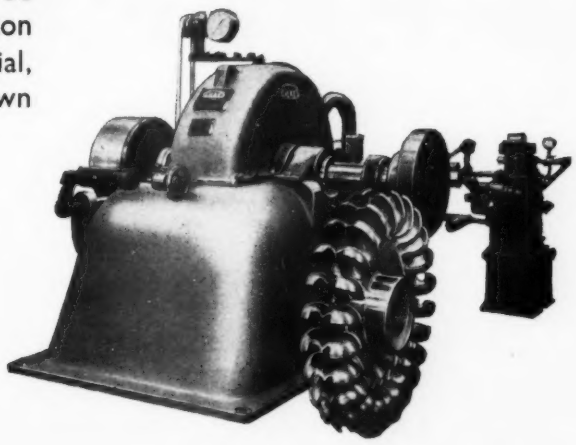
Readers in countries outside those listed above and who do not know the name of their local Atlas Copco company or agent, please write to Atlas Copco AB, Stockholm 1, Sweden.

Manufacturers of Stationary and Portable Compressors, Rock-Drilling Equipment, Loaders, Pneumatic Tools and Paint-Spraying Equipment

THE ATLAS COPCO GROUP OF COMPANIES

New Zealand Government photograph

The new Milford Sound Hotel is to be heated and lit by a single 635 B.H.P. Pelton Wheel. Complete reliability is essential, and the GILKES Pelton Wheel shown below is being installed.



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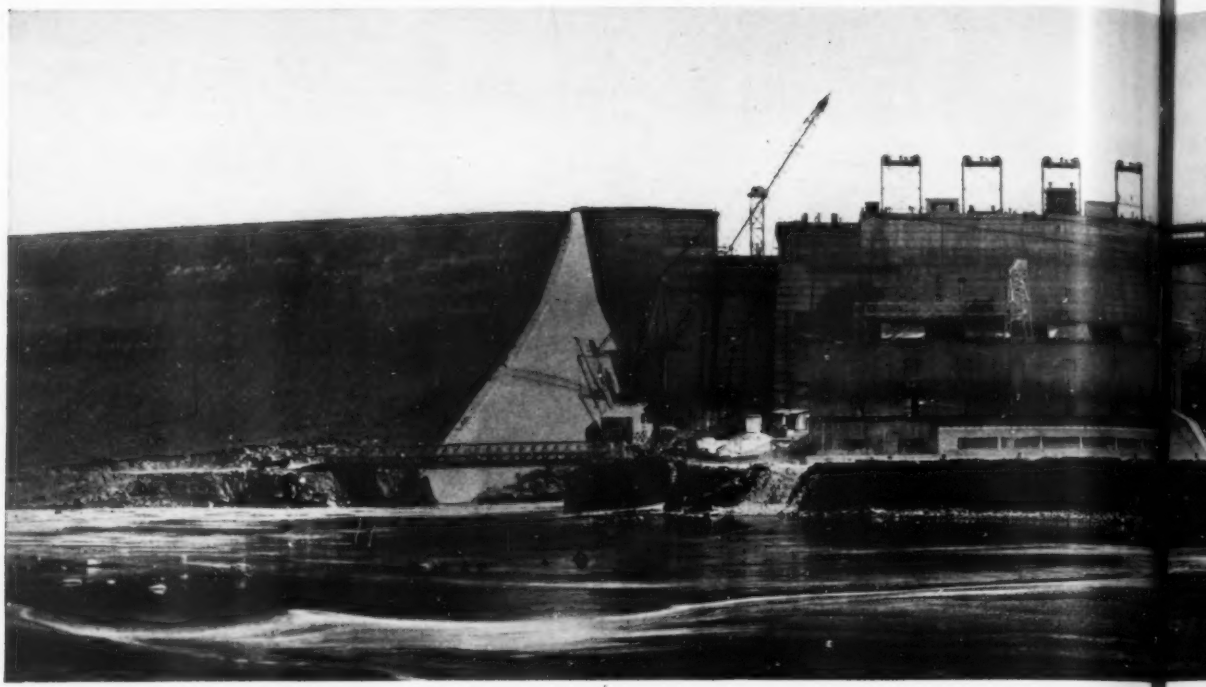


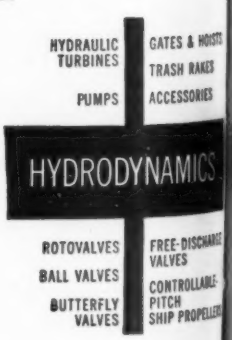
SMS-FRANCIS TURBINES AT LITTLETON DEVELOPMENT TO

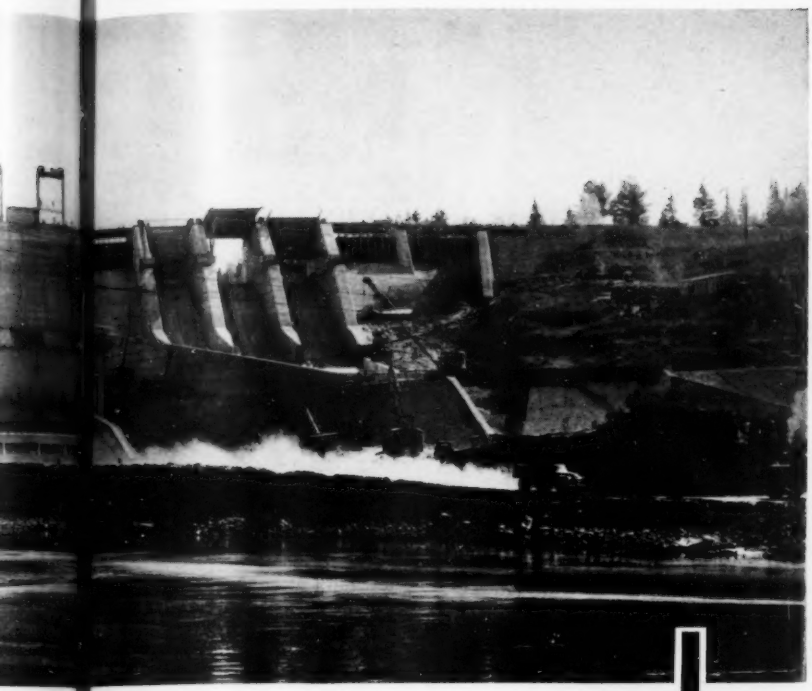
GENERATE PEAK POWER

To meet rapidly increasing demands within the New England Electric System's area, Moore Station near Littleton, New Hampshire, will soon go on the line delivering peak load power. Rated at 150,000 kw, this new hydro plant is the third and last on the Fifteen Mile Falls stretch of the Connecticut River. Including the Comerford and McIndoes Stations immediately downstream, this will give a total capacity of 310,000 kw in a river fall of 367 feet at this location. Thus the largest of New England's rivers becomes one of the most highly developed streams of its size.

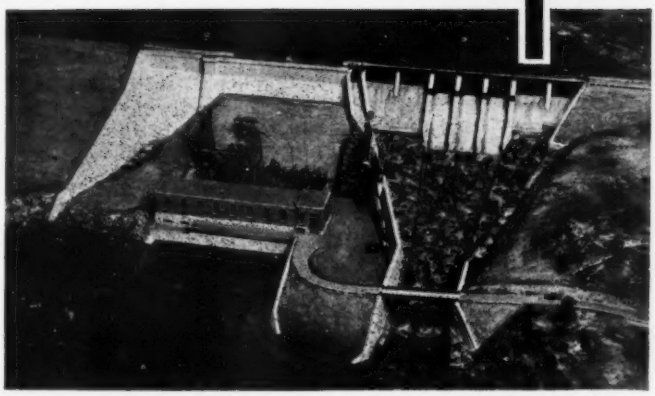
All three of the Fifteen Mile Falls plants are powered by SMS turbines. The four Littleton units are the vertical Francis type, each rated at 56,400 HP under a 150-foot head. SMS also provided four 18-foot x 24-foot fixed wheel intake gates for operation with an 84-foot head on the sill of the gate frame. The gates are designed for closing under full discharge and opening under balanced hydraulic conditions.

These three plants, with both SMS-Francis and Kaplan turbines as well as accessories, illustrate S. Morgan Smith's ability to handle the needs of any hydro project. Over three quarters of a century's experience in hydraulic design and manufacture stand behind SMS equipment. For full information, write S. Morgan Smith Company, York, Pennsylvania.

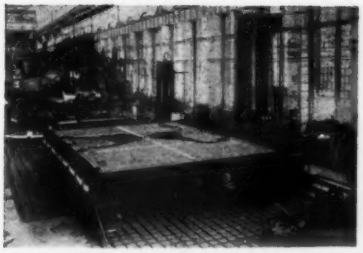




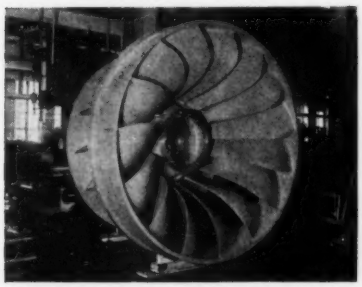
HYDRODYNAMICS



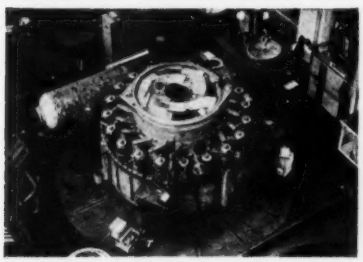
Looking upstream (top photo) across the tailrace area, the SMS-Fixed Wheel Intake Gate on Unit #3 can be seen being lowered into position atop the dam. Lower photo shows a scale model of the complete development.



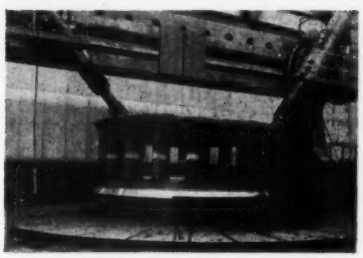
Two halves of a gate have been assembled and aligned on a 7-inch bar horizontal boring mill. SMS bores wheel axle holes in this manner to assure accurate alignment within close tolerances.



Unit #3's runner, completed and ready for shipment.



Complete distributor assembly is carefully shop-checked prior to dismantling for shipment.



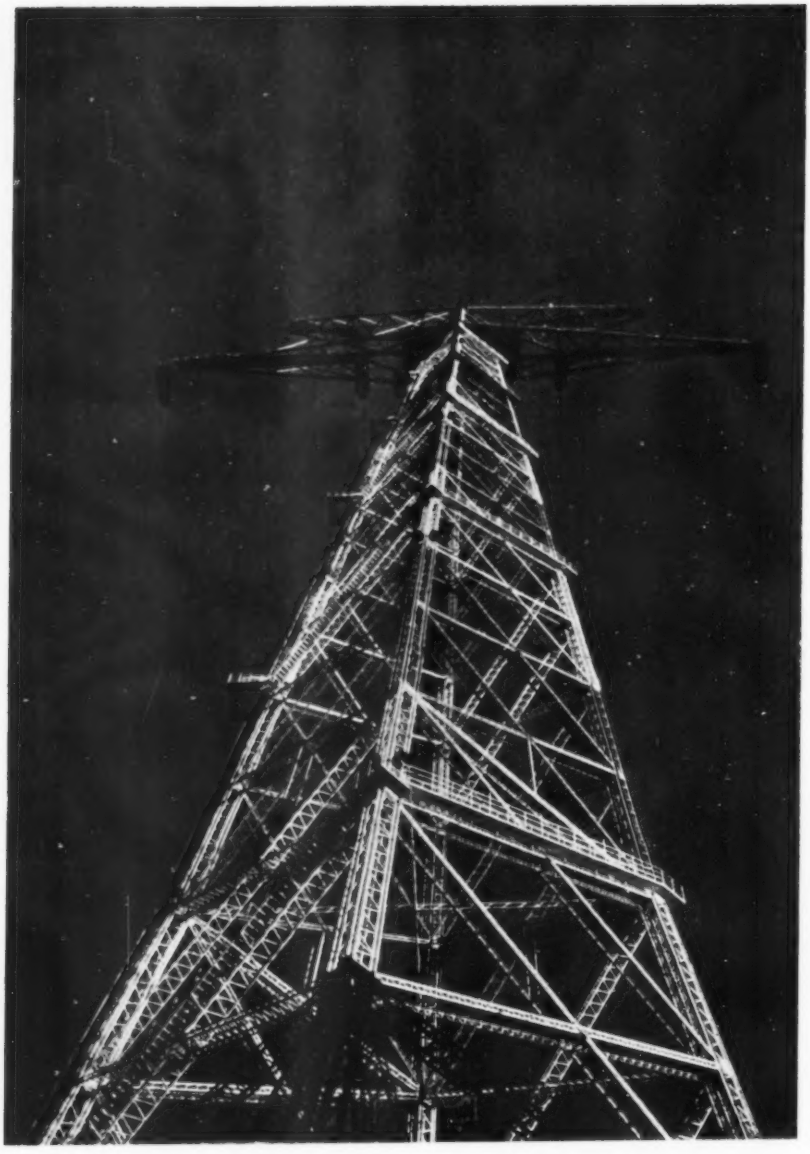
Here a 40-foot vertical boring mill machines riveting flanges on a cast-steel stay ring.

The 198-inch diameter riveted plate steel spiral case (with riveted cover plates) for Unit #1, taken during assembly at SMS Plant #2.

S. MORGAN SMITH

AFFILIATE: S. MORGAN SMITH, CANADA, LIMITED, TORONTO

Licensees: The Harland Engineering Company, Ltd., Alloa, Scotland
Tokyo Shibaura Electric Co., Ltd., Japan



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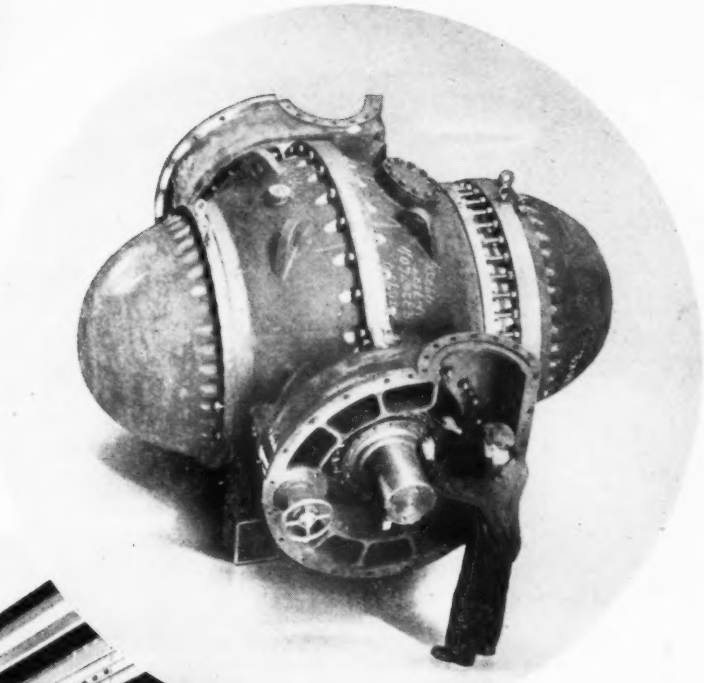
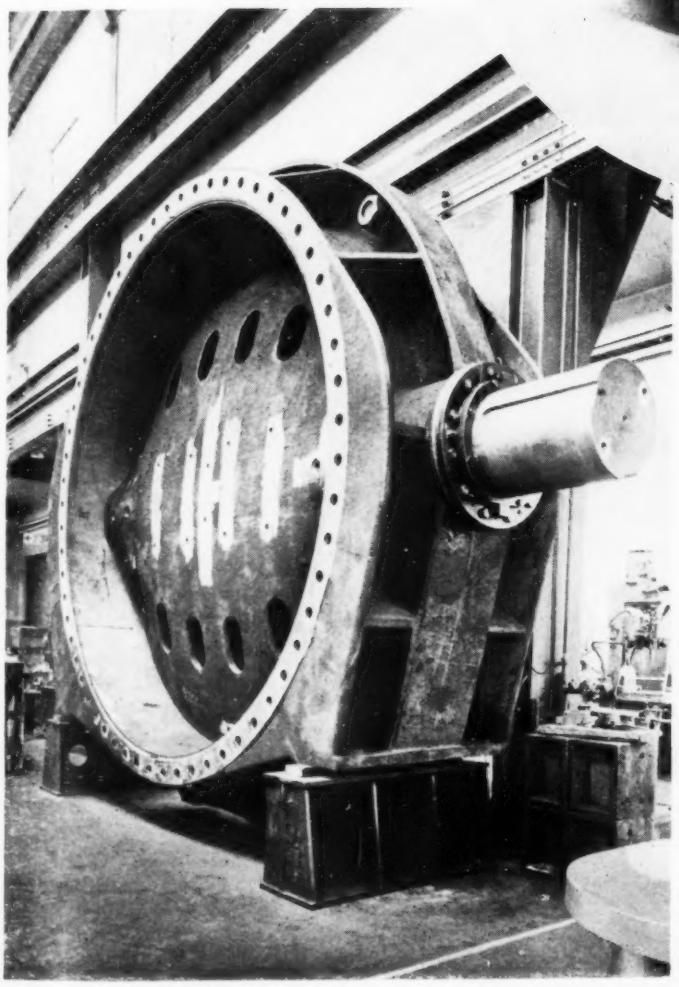




Above :

THE 59″ DIA. ROTARY VALVE

for the KMW Turbine installed in the Swedish Power Station of Tåsan in Värmland (turbine output: 48,200 H.P. at a head of 856 feet).

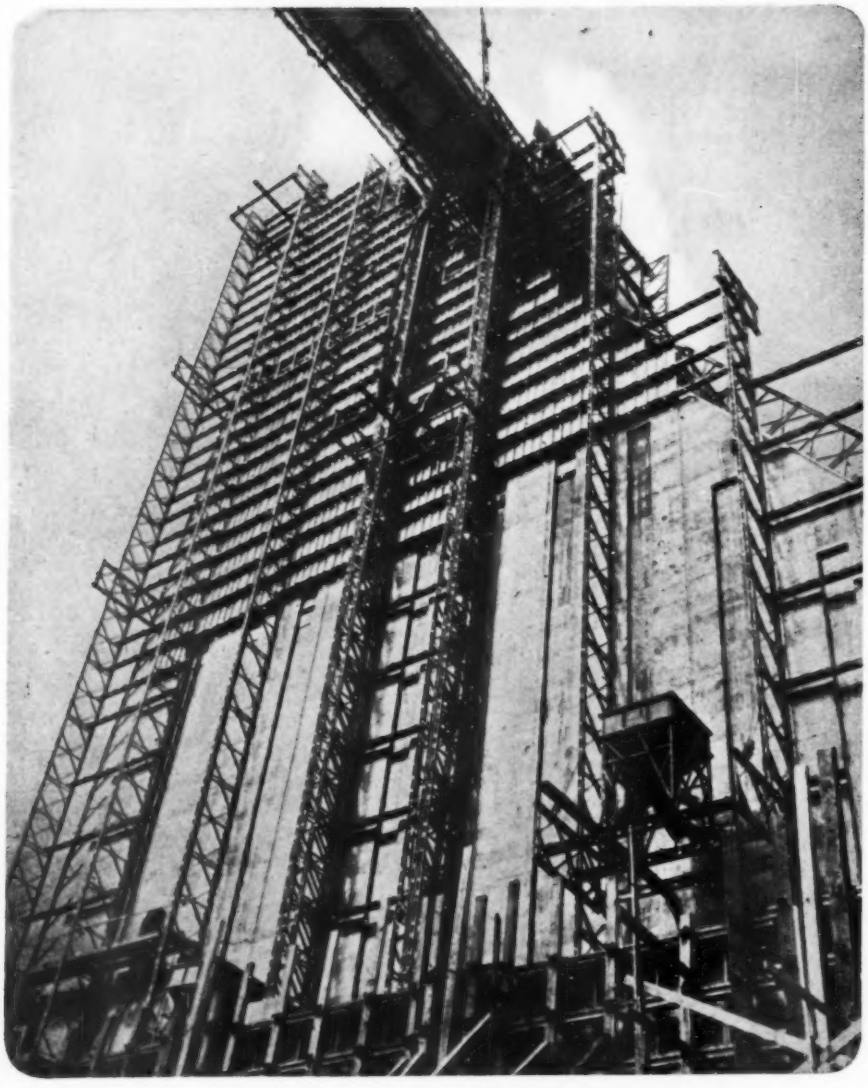
To the left :

THE 151″ DIA. BUTTERFLY VALVE

for one of the four KMW Turbines installed in the Spanish power station of San Esteban, belonging to the Saltos del Sil, S.A., Madrid (output of each turbine: 90,700 H.P. at a head of 338 feet).

AKTIEBOLAGET KARLSTADS MEKANISKA WERKSTAD

Karlstad • Sweden



Photograph by courtesy of the Ontario Hydro Electric Commission

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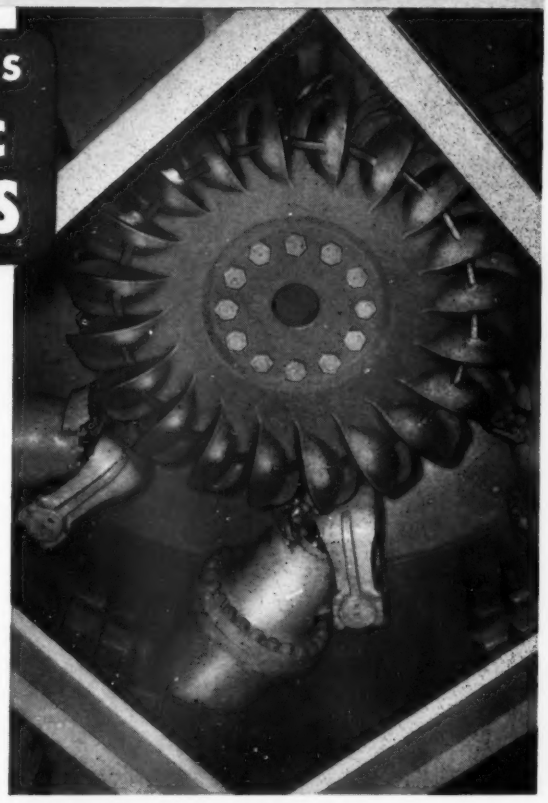
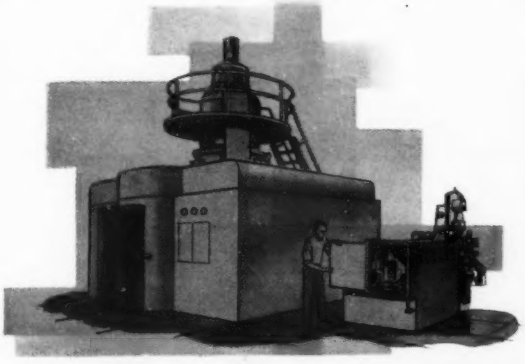
Hydraulic TURBINES



SIX-JET RUNNER and specially designed needle control mechanism are shown in this installation photo taken looking up from tailrace at the San Bartolo unit. Runner is fabricated from plate steel. Bucket bowls are welded directly to the wheel discs, eliminating bucket bolts. Operation can be with any combination of the six jets. The completed installation includes provision for remote control from the central station.



Allis-Chalmers Design Reduces Costs at San Bartolo Hydroelectric Plant

of the Comisión Federal de Electricidad

Mexico's newest hydroelectric plant, San Bartolo, in the northwest part of Estado de Mexico, features many economies that result both from operating conditions and plant design. Since the plant is to operate only six months of the year during the dry season (reservoirs are allowed to fill during the rainy season), a vertical shaft, six-jet impulse wheel was recommended by Allis-Chalmers engineers.

A six-jet instead of a one-jet runner permits a smaller diameter and higher speed. This lowers the cost of the turbine and saves on powerhouse structure, excavation and generator cost. And since one unit handles the entire capacity, there is need for only one bank of transformers and a single transmission line to connect with the rest of the Miguel Aleman System, which supplies power to the Mexican Power & Light Company, serving Mexico City and vicinity.

The Allis-Chalmers hydraulic turbine is rated 39,000 hp, 1233-ft head, 428.6 rpm and is direct-connected to a 28,000-kva, 13.2-kv, 0.9 power factor, three-phase, 50-cycle Allis-Chalmers generator with Kingsbury thrust bearing located above the rotor.

Other outstanding new Allis-Chalmers vertical impulse turbines include a 150,000-hp, 2500-ft head wheel at Kemano, Canada, and a 91,500-hp, 1325-ft maximum head wheel now being built for Donnells Power Plant in California. For information on these and other Allis-Chalmers hydro-turbine developments, see your nearby Allis-Chalmers representative or write Allis-Chalmers, Power Equipment Division, Milwaukee 1, Wisconsin, U.S.A. *Manufacturing plants in United States and Canada.*

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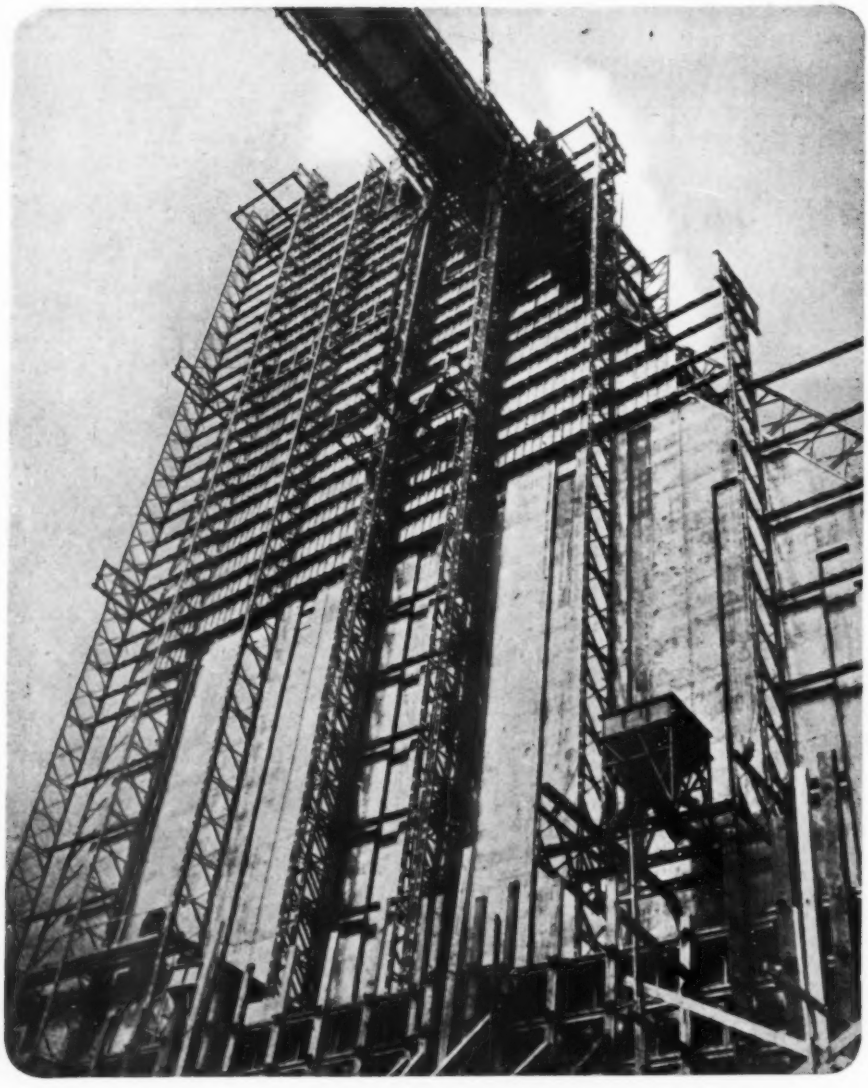

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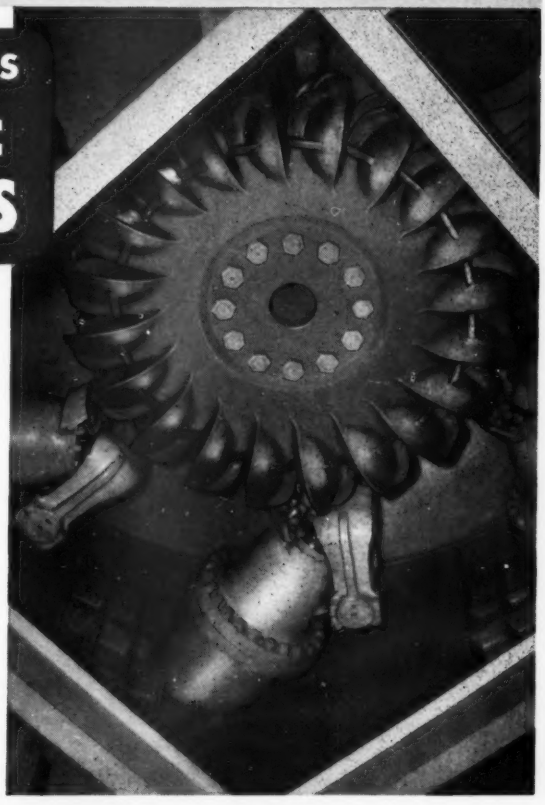
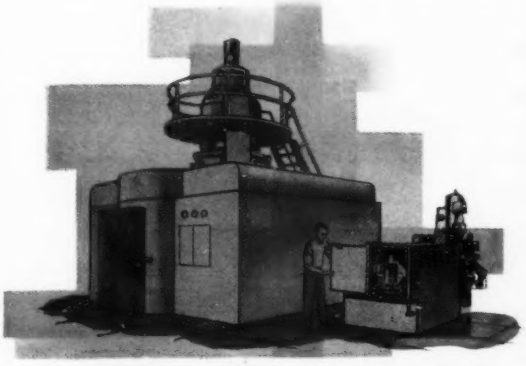


SIX-JET RUNNER and specially designed needle control mechanism are shown in this installation photo taken looking up from tailrace at the San Bartolo unit. Runner is fabricated from plate steel. Bucket bowls are welded directly to the wheel discs, eliminating bucket bolts. Operation can be with any combination of the six jets. The completed installation includes provision for remote control from the central station.



Allis-Chalmers Design Reduces Costs at San Bartolo Hydroelectric Plant

of the Comisión Federal de Electricidad

Mexico's newest hydroelectric plant, San Bartolo, in the northwest part of Estado de Mexico, features many economies that result both from operating conditions and plant design. Since the plant is to operate only six months of the year during the dry season (reservoirs are allowed to fill during the rainy season), a vertical shaft, six-jet impulse wheel was recommended by Allis-Chalmers engineers.

A six-jet instead of a one-jet runner permits a smaller diameter and higher speed. This lowers the cost of the turbine and saves on powerhouse structure, excavation and generator cost. And since one unit handles the entire capacity, there is need for only one bank of transformers and a single transmission line to connect with the rest of the Miguel Aleman System, which supplies power to the Mexican Power & Light Company, serving Mexico City and vicinity.

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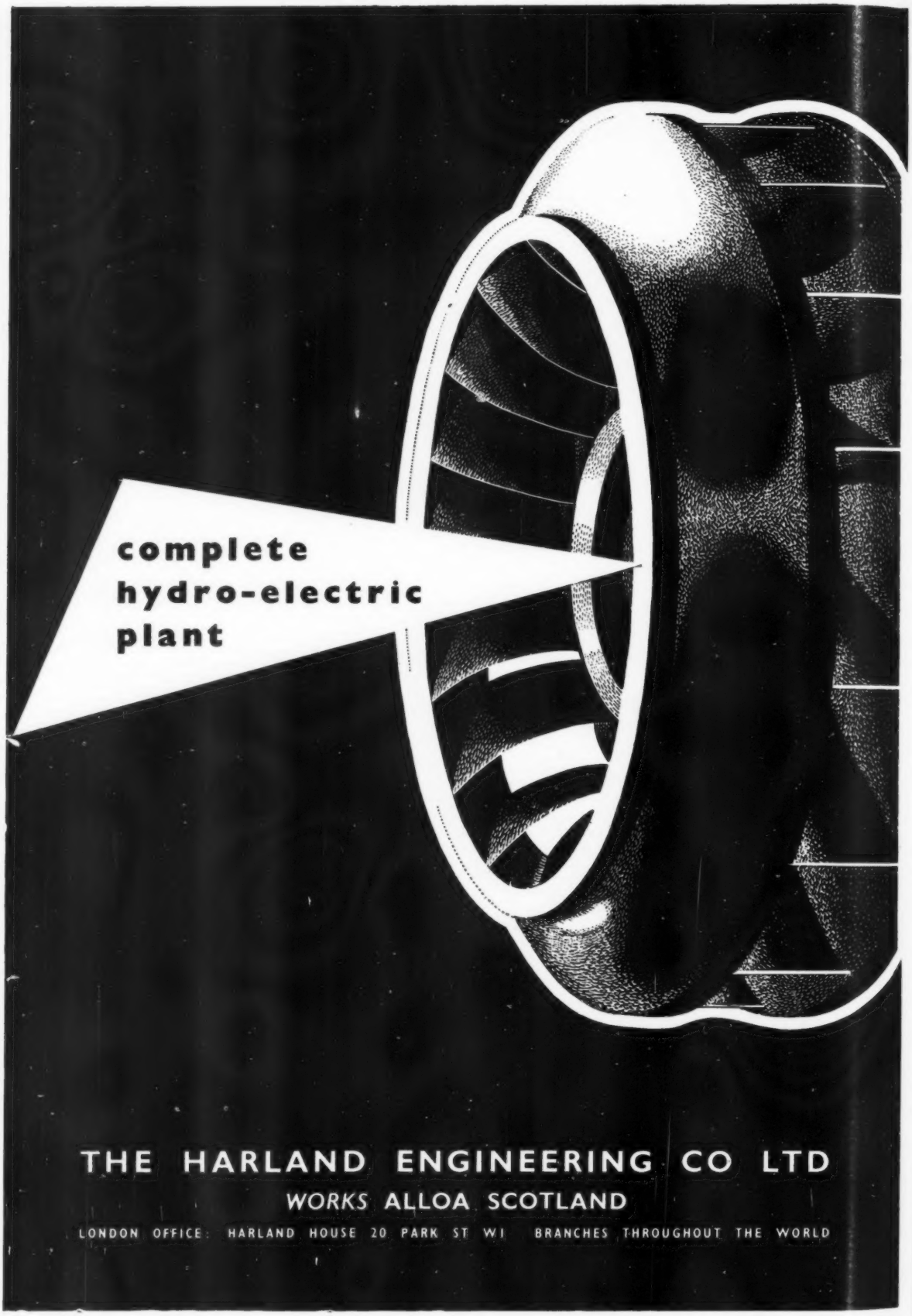

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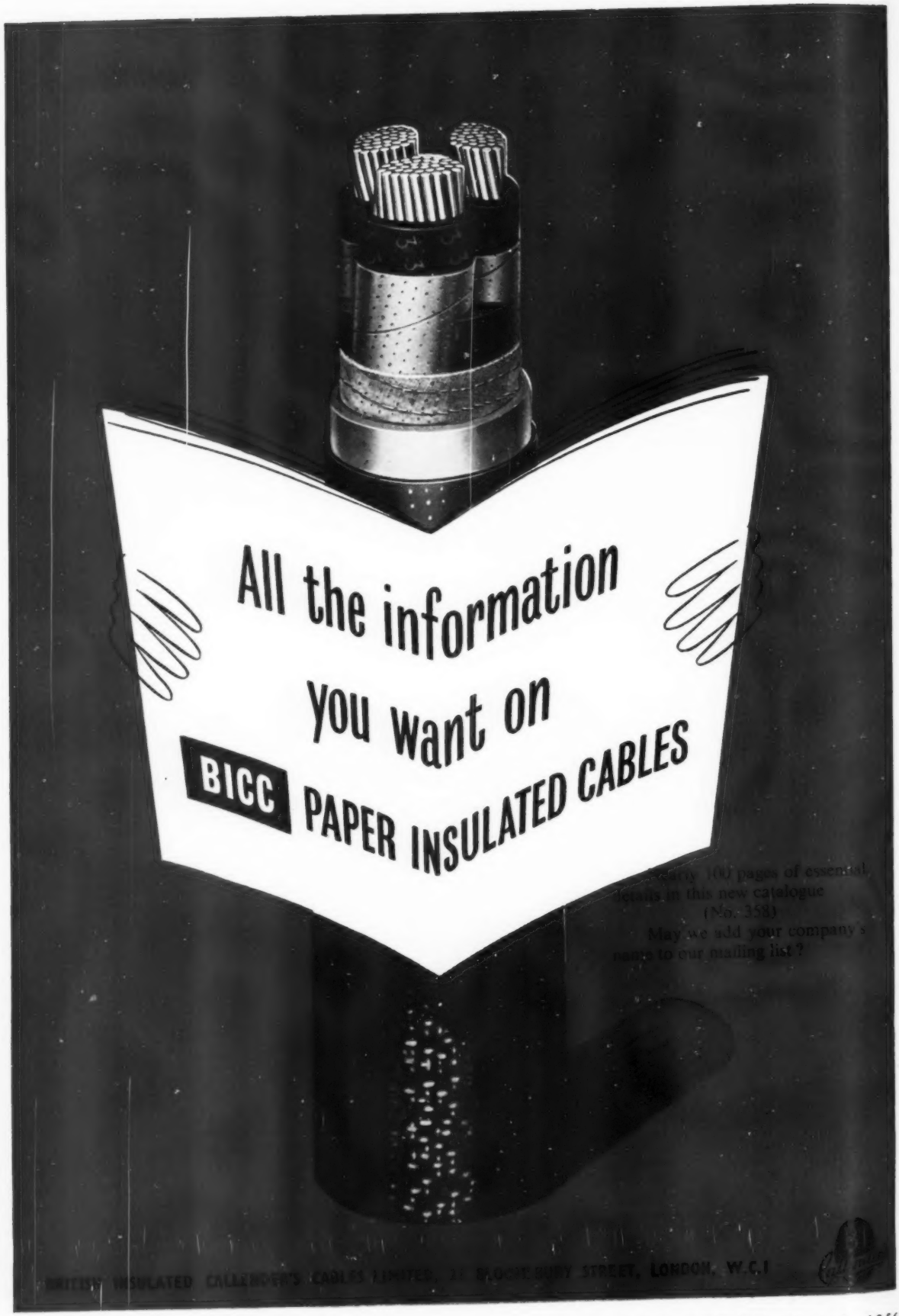
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Analysis of Arch Dams

AS we indicated in our February issue, a paper on "The Experimental and Mathematical Analysis of Arch Dams, with Special Reference to Dokan," was presented and discussed at a meeting of the Institution of Civil Engineers on January 17th. Any member of that Institution will search its *Proceedings* or *Journal* for the past decade in vain for a contribution more weighty, more lucid, more elegant, or descriptive of a more successful research effort.

In 1951, the Consulting Engineers to the Development Board of the Government of Iraq, Messrs. Binnie, Deacon and Gourley, sought the help of Professor A. J. S. Pippard, F.R.S., the Head of the Department of Civil Engineering at the Imperial College of Science and Technology, London, in connection with the design studies for a major dam to be constructed across the Lesser Zab River, at Dokan, in Iraqi Kurdistan. Professor Pippard and his colleague, Miss L. Chitty, had investigated highly complex structures of other types before, but the problems posed by the projected dam were so unusual and of such importance that the Professor, in addition to undertaking both experimental and analytical structural studies, arranged for the head of the Relaxation Division of the Department of Mathematics at the College, now Professor D. N. de G. Allen, and his assistant, Dr. R. T. Severn, to study the stress analysis of the dam as a problem in applied mathematics. The paper is the result of their work over three and a half years and, like other accounts of first-class research, has opened the way to more fields of study than are here dealt with.

The Consulting Engineers, faced with a major irrigation project with considerable water-power potentialities, decided on a site in the Dokan Gorge which lends itself to the construction of a concrete arch dam 385 ft. high and 1,170 ft. long at the crest, and retaining in a wide valley upstream of the gorge a reservoir of some 200 sq. km. of surface area. The general outlines of the dam, to which they gave a vertical upstream face forming part of a circular cylinder of 120 m. radius, were dictated by the need to allow for economical intake structures for a future power station to be constructed at the toe of the dam, and by the requirement of the simplest possible construction techniques to ensure the best use of relatively inexperienced local labour, but the difficulty of analysing particular profiles is well brought out in the paper. The theoretical problem of an arch dam constructed in a not entirely symmetrical valley and rigidly connected to the valley floor and sides is sufficiently formidable, even if the dam is assumed to be monolithic and built on homogeneous rock. To this problem have to be added those of variations in the properties of the foundation material and in temperatures, and of possible earthquake shocks. The data on which to operate, therefore, are necessarily idealised, and the authors of the paper start with a warning that excessive refinement in analytical treatment in this case may result in a false sense of security.

Because of the lack of precision in data, it appears to have been acceptable in the past to analyse some arch-dam designs by means of approximate formulae, which have given adequate service, possibly because of the exceptionally high factor of safety met with in arch dams, and the paper contains references to some of them. A more detailed method has been developed and used both on the Continent of Europe and in this country, and in its most elaborate form, as the trial-load method used by the United States Bureau of Reclamation, has been successfully applied to some of the most imposing structures built in North America and elsewhere. This method is based on the assump-

THE PRINTING TRADE DISPUTE

During the current dispute in the printing trade it will be our endeavour to maintain our normal standard of publication as far as practicable, but we must express our regret for any temporary departure therefrom that may be necessitated by the circumstances, and also for any possible delay in publication.

tion of part of the loading by water, earthquake, etc., being carried by vertical cantilevers to the foundation and the remainder by horizontal arching action to the abutments. At every one of a grid of selected points the displacements and rotations caused by the two actions must be the same, and the skill of the team employing this method lies in arriving at the correct distribution of the load between arches and cantilevers in a minimum number of trials.

The same assumptions as are made for the trial-load method also underlie the relaxation and the simplified structural analyses described in the paper. The relaxation analysis, as Professor Pippard pointed out in his opening remarks at the meeting, did not in fact allow for any variations either in the concrete in the dam or in the foundation or abutment rock; the structure was visualised as a "mathematician's dam" uniform in itself and with its rock support. The assumption of uniform elasticity in all directions, both in compression and in tension, makes it possible to formulate the rigorous elastic equations governing the components of stress at any point in the concrete or rock. The relaxation method, familiar to many of our civil-engineering readers from Sir Richard Southwell's studies of framed structures, consists of making controlled numerical corrections to certain assumed values, usually of stress, and employs certain mathematical approximations. However, given time, the answers this method provides can be brought as close to an exact solution as may be desired. In this case, the relaxation work was done in terms of the displacements at any point in the dam. A fourteen-page appendix to the paper explains in some detail both the connection between displacements and stresses and the relaxation process employed. A complete three-dimensional analysis was in fact undertaken by Professor Allen and his team, and their results are presented in numerous diagrams. These results are the closest approximation to the stress distribution throughout the dam (including, as Mr. G. M. Binnie emphasised, points in the interior of the mass) which is at present available for an arch dam of the given proportions. The full analysis, therefore, may be visualised as a tool for finding the stress distributions in arch dams of various proportions, and its results may be used as a touchstone for any other, simpler and speedier but not rigorous, method. The relaxation method may indeed be claimed to be sufficiently powerful to permit the analysis not only of elastic structures, but also of dams which—as may happen with concrete structures—would crack under tensile stresses exceeding a given value.

While the relaxation calculations were in progress, Professor Pippard and his team carried out tests on rubber models of dams of various shapes. These models proved to be of great value both in giving confidence in the three-dimensional relaxation technique which could be tested against observations on the models, and in providing initial values to be substituted in the relaxation pattern and so saving much computing time.

The paper refers, as did some contributions to the discussion, to a number of difficulties arising out of the uncertainties of the values and the effect of Poisson's ratio and Young's modulus, and these will doubtless be the subject of further study. Ultimately, the only limitations on accuracy, therefore, may be taken to arise out of the uncertainties of the site conditions and the inevitable lack of homogeneity in the structure.

It appears from the paper that Dokan dam will be most efficiently designed (the concrete saved as a result of the analysis of a preliminary profile was added to the crest, so increasing the reservoir storage by 40 per cent.), as well as aesthetically exceptionally pleasing.

World Power Conference, Vienna

THE Austrian National Committee of the World Power Conference has now issued a booklet giving the general programme of the Fifth Conference to be held in Vienna from 17-23 June, 1956. Two sections in the programme will be devoted to hydro-electric plants, one section dealing with the planning of entire schemes and the other considering technical problems of mechanical equipment and construction questions. Other divisions of interest to hydro-electric engineers will be concerned with the present status and development of power production and utilisation in individual countries, and with international co-operation in the production and use of energy.

During the Conference, whole-day excursions will be paid to the Ybbs-Persenbeug development now under construction on the Danube and to the stations of the Niederosterreichische Elektrizitaetswerke A.G. in the Kamp valley.

After the Conference a number of tours will be arranged for periods ranging from 10 to 14 days. Four main groups will visit mainly hydro-electric plants; one group will confine itself to plants in Austria, while the other groups will include plants in the German Federal Republic, Italy, and Yugoslavia respectively.

New Waikato Hydro Project

WORK on the 84,000 kW Ohakuri project, between Atiamuri and Orakei Korako, on the Waikato River, New Zealand, will begin early this year. Ministry of Works gangs have been clearing trees before excavating the power-house and headrace sites. Heavy machines and staff will soon be moved to Ohakuri from the Whakamaru scheme, on which work is nearly finished. At Ohakuri the diversion tunnel, 1,400 ft. long and 25 ft. in diameter, is being driven by a firm of contractors. This work began early this month.

Proposed Cable Across Cook Strait

MR. M. G. LATTA, chief engineer of the New Zealand State Hydro-Electric Department, has published a report in which he advocates a full and early investigation into the possibility of laying a submarine cable across Cook Strait, a distance of about 30 miles, between the North and South Islands. He regards the project as technically feasible, and considers that it would be of the utmost economic benefit as it would render the abundant hydro-electric potential in the South Island available to the country as a whole. Such a power link, in fact, would render it unnecessary to consider nuclear power for many years.

On the short-term policy Mr. Latta considers that the remaining sites on the Waikato river should be developed as quickly as possible, that geothermal power should be further investigated, and that a 50-60

MW gas-turbine peak-load station in Wellington should be considered to operate in conjunction with the base-load steam stations at Mercer and Wairakei.

Generators for Bhakra Dam

METROPOLITAN - VICKERS ELECTRICAL CO. LTD., through its associated company Associated Electrical Industries (India) Ltd., has obtained an order from the Punjab Government covering five water-turbine-driven a.c. generators for the first stage of the Bhakra dam project on the Sutlej River in Northern India. This scheme was described in our May and June 1954 issues. Each generator will have an output of 100,000 kVA at 166·7 r.p.m., the voltage being 11 kV three-phase 50 c.p.s. and the power factor 0·9. They are to be driven by Francis-type turbines of 125,000 h.p. each. The generators will be of the vertical-shaft type with a thrust bearing above the rotor and two guide bearings, one above and one below. Among the ancillary equipment included in the order are five Metropolitan-Vickers type VTSR automatic voltage regulators, which are of the quick-response magnetic-amplifier type.

The order is one of the largest ever received by a British manufacturer for this type of equipment, being valued at over £1 million, and the project, when completed, is expected to be the largest hydro-electric scheme in Asia.

Asme Holds First Cavitation Seminar

REPRESENTATIVES of industry, colleges and research actively engaged in cavitation research recently attended the first cavitation seminar to be held by the American Society of Mechanical Engineers at Allis-Chalmers Manufacturing Company in West Allis, Wis. The seminar concerned itself with operating characteristics of magnetostriction equipment, laboratory demonstrations, parameter variations, and comparisons with other methods of determining cavitation resistance.

Engadin Valley Development

THE two concerns interested in the development of the Upper Inn, "Konsortium Engadiner Kraftwerke" and "Konsortium Innkraftwerke,", amalgamated last September under the title of "Engadiner Kraftwerke A.G." (Engadin Power Works Ltd). In an interim report published recently, the new company announces that the first stage of the development contemplated will be restricted to works erected on Swiss territory; these works will involve an installed capacity of 419,000 kW. Out of the mean yearly production of 1,490 million kWh, winter energy does not exceed 470 million kWh; it is however expected that the setting up of the Livigno reservoir will substantially improve winter production.

Caroni Contract

A CONTRACT valued at $8 million has been awarded to a German-Swiss consortium for the supply of three 50 MW turbines for the development on the Caroni River, a tributary of Venezuela's principal river, the Orinoco. The consortium includes the Swiss Oerlikon Company and the two German firms, A.E.G. and J. M. Voith. The turbines are due to be installed by March 1958, and a fourth turbine may be ordered later. As briefly outlined in our December 1954 issue, this represents the first of four stages envisaged to harness the river, which should have a total developed capacity of the order of 8,000 MW. The consulting engineers are Sir William Halcrow & Partners.

Surinam Project

A LARGE dam on the Surinam river, a hydro-electric installation, and an aluminium factory having a capacity of 40,000 tons a year, are planned by the Government of Surinam (previously Dutch Guiana). The project would require a loan of approximately £8 million. It is probable that the Dutch Government and Dutch industrial concerns may take an interest in the project. Surinam is a big producer of bauxite.

Tiszalok Gives Power in March

THE hydro-electric station served by the Tiszalök dam in north-east Hungary should be giving its first power this month, according to Professor Emil Mosonyi, chief of the planning department of the Hungarian National Water Board. At the time of Professor Mosonyi's statement, No. 1 generator was nearing completion and was due for test by the end of February. Two more machine units are to be added during the next twelve months.

Bersimis Generators

LAST month we recorded that Neyrpic Canada Ltd. had been awarded the contract for the last four 176,000 h.p. turbines for Bersimis, and stated that these turbines would drive the four 138 MW alternators ordered last summer from Metropolitan-Vickers Electrical Co. Ltd. Our statement regarding the alternators was made under a misapprehension. The facts are that the Metropolitan-Vickers alternators are for the first four units, and that the Neyrpic turbines will drive Canadian General Electric generators.

Glockner-Kaprun Progress

THE final step in major construction work at Glockner-Kaprun is marked by the recent completion of the Mooserboden dam. The heart of the whole system is formed by the two big artificial lakes, Mooserboden at 6,000 ft. above sea level, and the Wasserfallboden at 5,000 ft. The Limberg dam, part of the Wasserfallboden system, nearly 400 ft. high, was completed in 1951, when work began on the Mooser and Drossental dams, which now have been completed as the final dams to the Mooserboden system. Thirty million cu. ft. of concrete were used on the last two dams alone. The annual output of the Kaprun plant will be 825 million kWh.

NOTICE TO READERS

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Fig. 1. Vinstra machine hall in course of construction

Vinstra

When completed, the Vinstra power plant will have a capacity of 180 MW. It is an excellent example of current Norwegian practice in underground station design. The supply tunnel is one of the longest in the world, the turbines are the highest-head Francis machines in Norway, and the transmission line to Oslo forms an important section of the Norwegian 220 kV grid

PART ONE

THE Vinstra development, in Opland, Norway, is the property of an intermunicipal company formed in 1946 under the title of Vinstra Kraftselskap, two-thirds of the capital being owned by Oslo Lysverker—the owners of the Hol development*—and the former Aker Elektrisitetsverk, and one-third by Hamar, Vang og Furnes kommunale Kraftselskap. The bulk of the power is fed to Oslo and district by a 220 kV overhead line, but a proportion is absorbed locally and in Gudbrandsdal to the north.

The village of Vinstra, in the Peer Gynt country, lies about 260 km. north of Oslo on the road to Trondheim via Dombås and on the confluence of the river Vinstra with the Lågen. Vinstra power station is in the hillside about 6 km. south of Vinstra, and the catchment area lies to the west of Vinstra on the south-eastern flank of the Jotenheim massif.

The first stage of the development, comprising two

* See WATER POWER Oct., Nov., Dec., 1955, pp. 362, 400, 469.

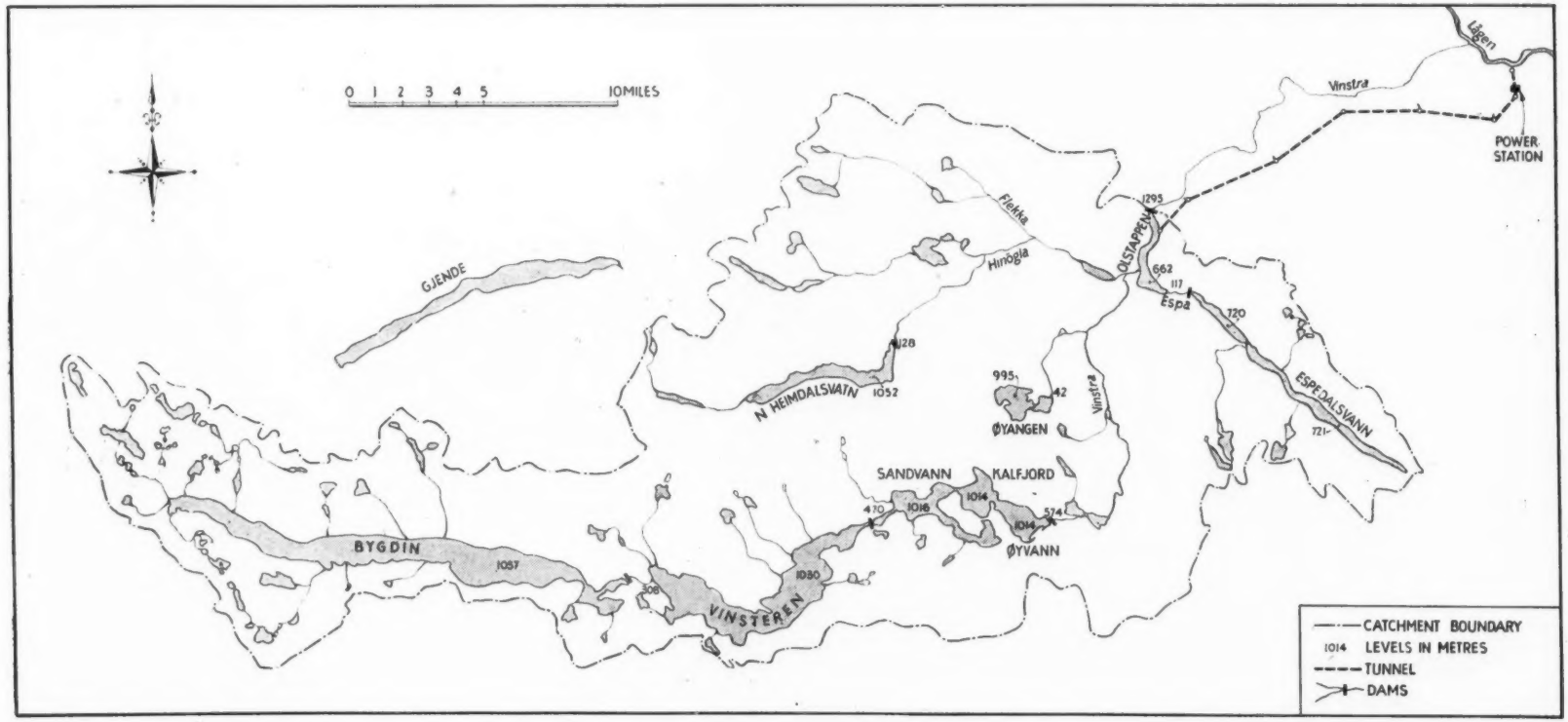


Fig. 2. Map of the catchment area of the Vinstra development, showing the lakes that are being impounded to constitute the storage, their impounded levels, and the dams involved. The small circles on the path of the tunnel from Olstappen to the power station denote the sites of the construction adits

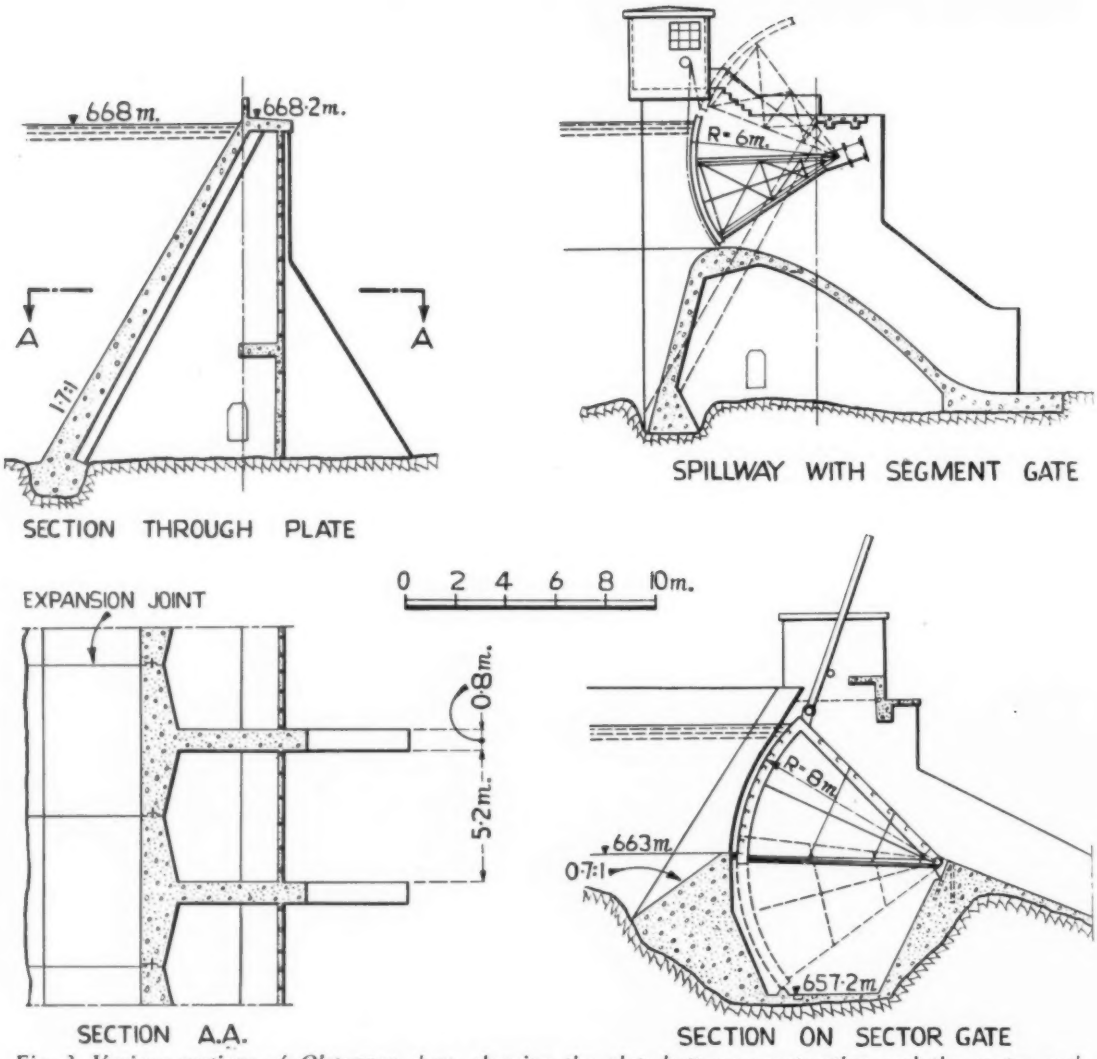


Fig. 3. Various sections of Olstappen dam, showing the plate-buttress construction and the sector and segment gates

50 MW sets, commenced operation in 1953, and a third 50 MW set commenced operation in January, 1955. A fourth and final 50 MW set will be erected in 1958.

Catchment Area

A map of the catchment area appears in Fig. 2. On account of the wide extent of the catchment—1,290 sq. km.—it has been possible to secure the necessary storage by building low and simple dams. For the three generating sets the storage, totalling 480 million cu. m., has been provided by lakes Bygdin, Vinsteren and Olstappen. The bulk of this storage—350 million cu. m.—is afforded by lake Bygdin, the level of which has been raised from 1,048 to 1,057 m., and which discharges to lake Vinsteren through a tunnel. Lake Vinsteren has been impounded by an earth dam with a concrete core and a central concrete spillway, and by regulating the water level from 1027·5 to 1031·5 m. a storage of 90 million cu. m. has been provided.

Lake Olstappen forms the intake basin and has been raised from 655 to 668 m., giving a storage of 30 million cu. m. and a gross head on the turbines of about 448 m.

For the complete regulation for the four units the storage capacity is being increased to 625 million cu. m.

Olstappen dam, which we saw in an advanced stage of construction, and was completed in January, 1955, is the largest in the development. It is a concrete structure of the plate buttress type favoured in Norway, and is 165 m. long at crest and 15 m. high to lowest foundation. It has a main sector gate and spillway to pass flood water and a subsidiary sector gate for logging.

The remaining additional storage will be afforded by lakes Sandvann, Kalfjord and Øyvann, lying between lakes Vinsteren and Olstappen, at a level of 1,014 m., which will yield 75 million cu. m., Nedre Heindalavatn, lying in a valley to the north of the

Bygdin-Vinsteren-Øyvann watercourse, which will also yield 40 million cu. m., and Espaldsvann, in a valley to the east, will be impounded to yield 32 million cu. m.

At completed regulation the mean flow will be 33 cu. m. per sec., equivalent to an annual production of 1,000 million kWh based on 5,000 hours per annum. With all four units on full load the flow will be 56 cu. m. per sec. The gross head on the turbines is 448 m.

It will be noted that a head of 340 m. is available between Øyvann and Olstappen, and it is planned eventually to build a new power plant, comprising two 70 MW sets, between these lakes.

Supply Tunnel

The Vinstra intake lies on the right bank of lake Olstappen, a short distance from the dam, and is a conventional structure equipped with a trashrack and a sliding sluice. Some difficulty was experienced during construction due to a mass of moraine at the site of the intake, but this material was removed by high-pressure water jets.

The supply tunnel, which is 6 m. wide and 30 sq. m. in cross section, is 23·7 km. long and is claimed to be the longest water tunnel in Europe, if not in the

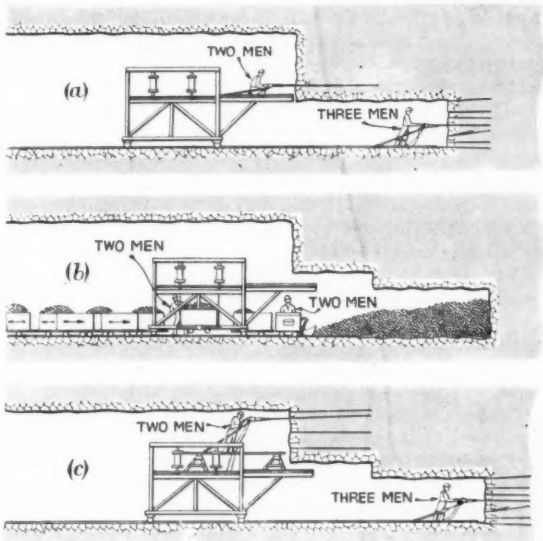


Fig. 4. Diagrams showing sequence of operations in driving the supply tunnel

Fig. 5. Drilling platform with shunting device to handle trucks

world.* It was driven from five adits in addition to the ends, giving a total of 12 working faces. Work was continued on all three shifts, each face being manned by five miners and a working foreman on each shift.

The use of this comparatively small force was made possible by the adoption of what is now generally known as the Swedish method of tunnelling, using light airleg drills and tungsten-carbide-tipped drill steels, and the details of procedure were worked out in collaboration by Vinstra Kraftselskap, A/S Høyer Ellefson, the civil-engineering contractors, and A.B. Atlas Diesel, who supplied all the drills, jumbos, loaders, compressors and other tunnelling equipment.

The rock was a phyllitic schist and was very tough, so that it became desirable to carry a bottom pilot tunnel 2·5 m. high, in advance, and to bench the roof to full height at a distance of 7-8 m. behind the pilot tunnel. To reach the roof ripping a special rail-mounted drill carriage was designed by the Projecting Department of A.B. Atlas Diesel. The sketches given in Fig. 4 show the sequence of operations. On the first shift the pilot tunnel was drilled for an advance of 2 m. and the lower part of the roof drilled for an advance of 4 m. (Fig. *a*), and these holes blasted and mucked out (Fig. *b*). On the second shift the pilot tunnel was drilled for a further advance of 2 m., the remainder of the roof drilled for a 4 m. advance (Fig. *c*), and the round fired. Mucking took place for the remainder of this shift and throughout the third.

Mucking was carried out by Atlas type LM loaders discharging into 1·8 cu. m. capacity metre-gauge trucks. These trucks were transferred from the empties to the fulls road very simply by an arrangement incorporated in the drilling carriage as sketched in Fig. 4b and seen in action in Fig. 5. Below the carriage platform a cross boom was placed, pivoted at the end adjacent to the fulls road and coupled at the empties end to two pneumatic lifting cylinders. A traveller ran on this cross boom and was provided with four hooked ropes for attachment to lifting eyes on the corners of the truck to be lifted. When the truck had thus been attached, the pneumatic cylinders were operated to raise the boom and lift the truck off the rails. This action also brought the boom into a position in which it sloped downwards towards the fulls road, so that the truck could be pushed over to the other track with little effort, after which, releasing the pneumatic cylinders lowered the truck on to the rails.

The adoption of these methods resulted in an average advance on each face of 25 m. per week, equivalent to an excavation of 6·35 sq. m. per man-shift if the foreman be included. In all, about 721,000 cu. m. of rock was removed from the tunnel and the adits.

Some trouble was experienced with sections of bad rock, some of which had to be temporarily bypassed and then opened out with the help of timbering and lined with concrete, using telescopic steel formwork and a concrete pump. About 1,500 m. of tunnel had to be lined.

At the adits and just in advance of the surge chamber sumps were cut to receive loose rock, and each adit was sealed off from the tunnel by a concrete bulkhead in which was embedded a 1·8 m. diameter pipe fitted with a removable cover to afford access for inspection.

Near the entrance to each adit a camp for 50 men was built, together with the appropriate stores and repair shops. One of these camps is seen in Fig. 6.

Surge Chamber and Penstocks

Originally the tunnel was designed to terminate in a subterranean surge chamber, but in view of the rock conditions it was found preferable to lead the tunnel to a comparatively small distributing chamber from which two vertical shafts rose to an open chamber cut in the mountainside. The arrangement can be seen in Fig. 8. The distributing chamber has an expansion

Fig. 6. Construction camp at one of the supply-tunnel adits

Fig. 7. Empty trucks on their way to one of the construction adits

* This is true only if the penstock and tailrace tunnels are taken into account. The exact lengths, in English units, are as follows: Supply tunnel, intake to surge chamber, 77,736 ft.; penstock tunnel, 2,460 ft.; tailrace tunnel, 3,280 ft.; total 83,476 ft. If the supply tunnel only be taken into account the length of this tunnel is exceeded by that of the Loch Treig-Lochaber tunnel serving the Lochaber works of the North British Aluminium Co. Ltd., near Fort William, Scotland. This tunnel is 79,327 ft. long from intake to surge chamber, with a further 431 ft. from surge chamber to portal.—EDITOR, WATER POWER.

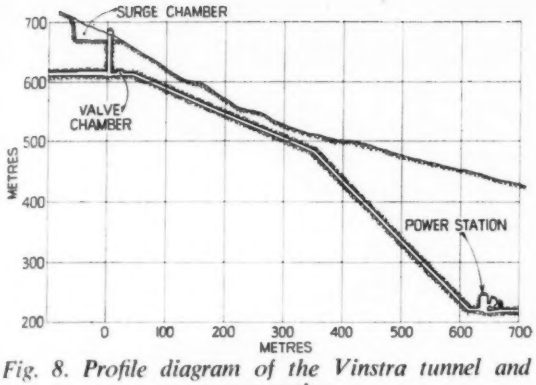


Fig. 8. Profile diagram of the Vinstra tunnel and power station

space of 500 cu. m., the shafts are 72 m. long and about 7 m. in diameter, and the open chamber has a capacity of 8,000 cu. m. The shafts are lined with reinforced concrete.

At the downstream end of the distributing chamber is a reinforced-concrete bulkhead carrying the inlets to two penstocks, each supplying two turbines. Each inlet is protected by two trashracks which can be hoisted for clearing through a shaft to a winch house on the mountainside immediately in front of the open surge chamber. The first of these racks is of the usual flat type, but the other is hook-shaped so that loose debris is carried into the basket formed by the base of the hook and is thereby lifted to the surface.

Immediately downstream of the distributing-chamber bulkhead is a valve chamber. Each penstock is fitted with two Kvaerner-Brug 2,600 mm. butterfly valves (Fig. 9), the first closing automatically in the event of an emergency, and the second being operated by remote manual control from the power station. They are designed for a head of 55 m.

From the valve chamber a penstock tunnel extends a distance of 710 m. to the underground power house. As will be seen from Fig. 8, it is in two sections, the first having a slope of 1 in 2 and the second a slope of 1 in 1. The tunnel is dimensioned to take the two steel penstocks side by side together with the usual erection and inspection tracks. Each penstock is 2·6 m. in diameter in the supper part, reducing to 2·0 m. at the power part, where it bifurcates into two 1·3 m. diameter pipes to feed the turbines. The lower portions of these penstocks are supplied by Ferrum Montage A/S, Oslo, and the upper portions are Y pieces by A/S Kvaerner-Brug, Oslo. At the time of our visit the first penstock was in commission and the second in course of erection.

In this, as in some other Norwegian stations, open penstocks in a tunnel were preferred to pressure shafts. It was considered that two pressure shafts would have been needed, so that the cost balance was not unfavourable to open penstocks, and the facility with which such penstocks can be inspected and maintained was regarded as a valuable asset.

Power Station

The layout of the underground power station is an excellent example of current trends in Norway and contains many points of interest. Some of its features will be gathered from the plan, Fig. 10, and the cross-sectional elevation, Fig. 11, but one point that is not evident from the illustrations is that the station is located about 1 km. into the rock. This has been done on account of the gentle slope of the toe of the mountain, and it has enabled the penstock tunnel to be shortened to less than half the length that would have been required for a location in the open or just under rock cover. By this means about three million Norwegian kroner (£150,000) has been saved in tunnelling and penstock costs, in addition to the saving in head loss in the penstocks.

Three tunnels extend from the hillside to the power station, for transportation, cables, and tailwater respectively. The transport tunnel is 1,000 m. long and 30 sq. m. in section, and carries a standard-gauge railway track which forms the termination of a branch line from Harpefoss station about 3 km. away. As will be seen from Fig. 10, this track serves a cross track in the transformer hall, the erection bay of the machine hall, and a chamber behind the machine hall in which a special trolley on a wide-gauge cross track enables penstock sections to be handled by rail right to the erection trolley in the penstock tunnel. Owing to the convenience of the handling and transport arrangements, any plant in need of major repair can be returned by rail to the maker's works, where full facilities will be available, in preference to attempting repair at the station. Nevertheless, a workshop is provided adjacent to the erection bay to cope with normal maintenance.

The cable tunnel is on the opposite side of the station and runs off at an angle to the transport tunnel to a point on the hillside convenient for the commencement of the overhead line. It is somewhat longer than the transport tunnel—1,200 m.—although its section is only 9·5 sq. m.

The tailrace tunnel follows the route of the transport tunnel, and is also 1,000 m. long by 30 sq. m. section. It has a surge chamber of about 1,300 cu. m. capacity.

Another feature not evident from the drawings is the means adopted to protect the station from the effects of a burst penstock. The penstock tunnel is isolated from the station by self-closing steel bulkhead

Fig. 9. One of the Kvaerner-Brug valves in the upstream valve chamber

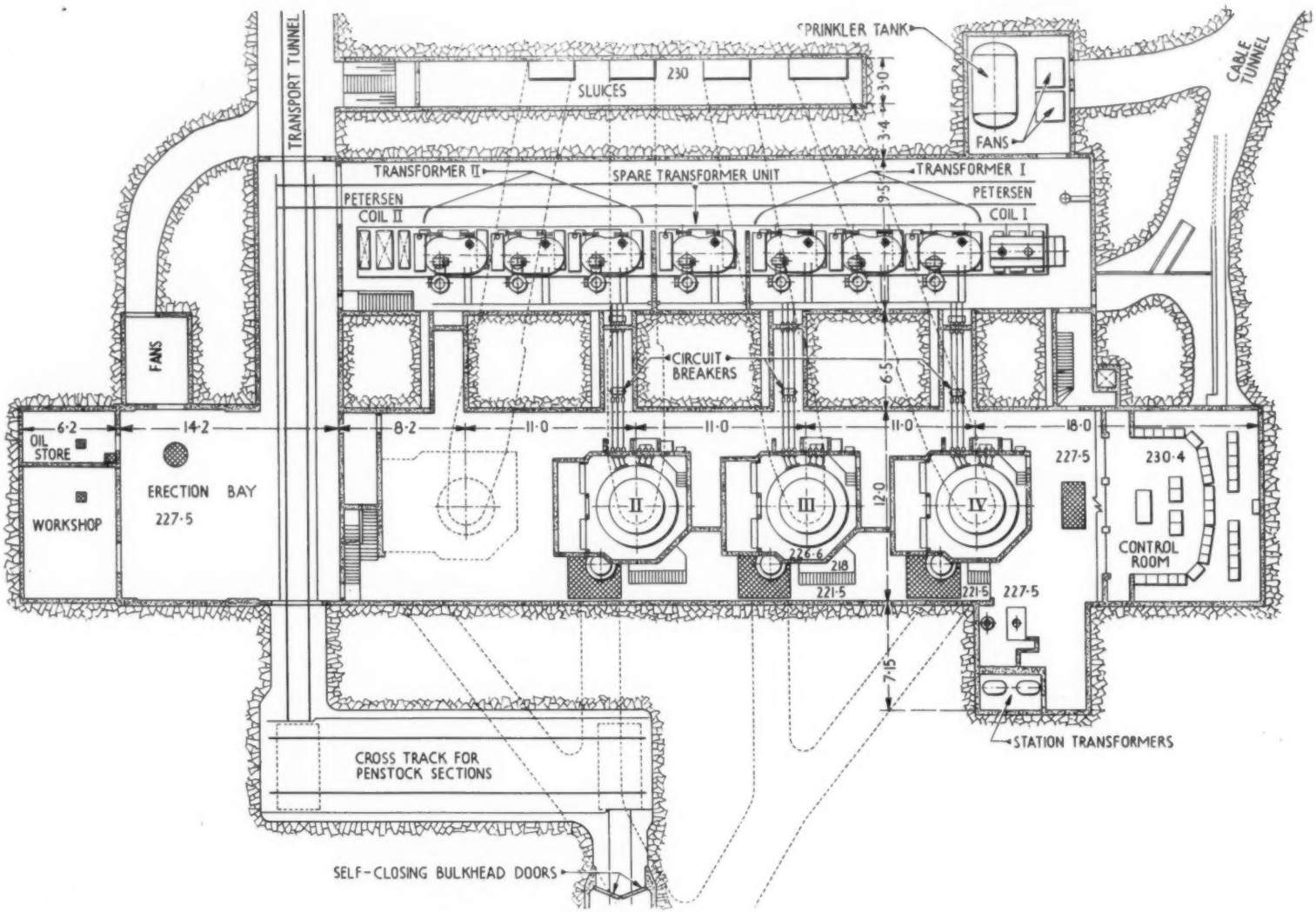


Fig. 10. Plan of the underground power station at Vinstra

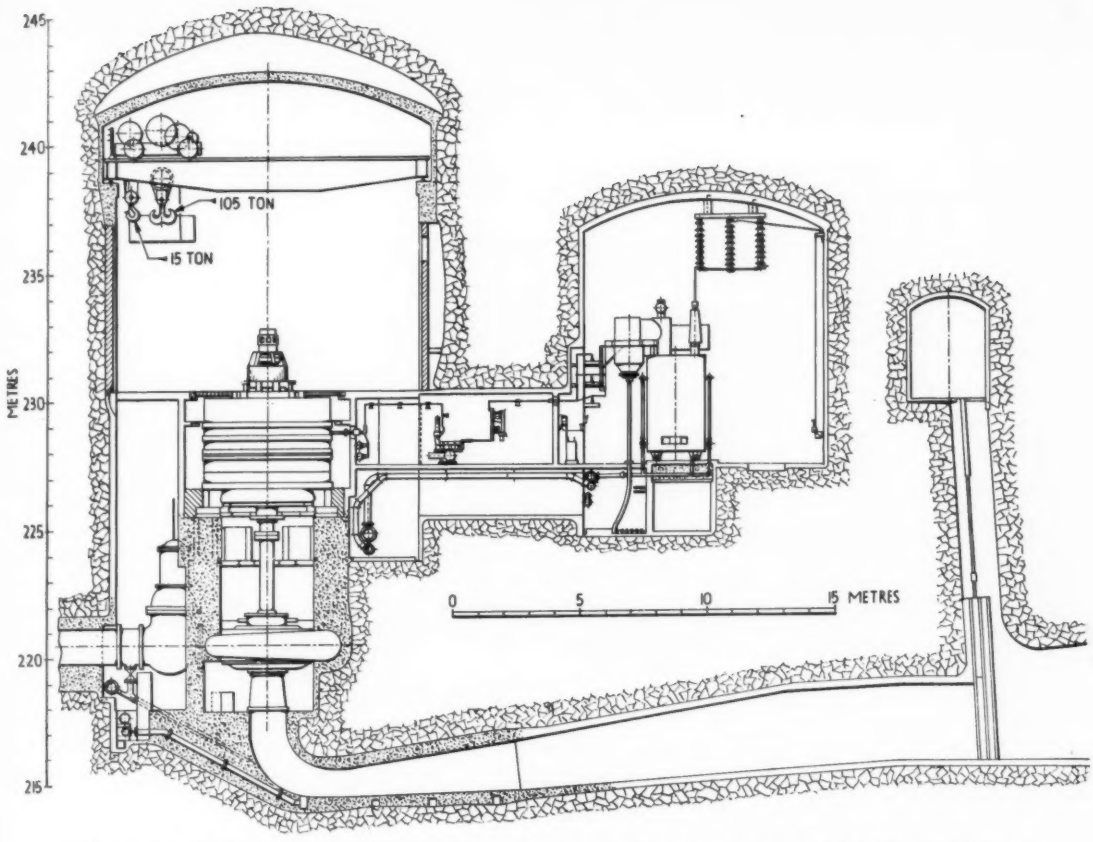


Fig. 11. Section through Vinstra power station taken on the line of one of the 50 MV A generating sets

doors, visible at the bottom of Fig. 10, and a connecting tunnel (not shown on the drawings) has been driven to divert any flood from the penstock tunnel direct to the tailrace tunnel on the downstream side of the draught-tube gates.

To guard against the effects of a burst downstream of the bulkhead between the penstock tunnel and the station, a short length of pipe has been let into the bulkhead and fitted with a bolted-on cover on the upstream side. This cover will withstand the pressure of water in the penstock tunnel, but a water pressure coming from the power-station side will blow the cover off its bolts, allowing the flood to evacuate to the tailrace through the connecting tunnel as in the former case.

A further noteworthy feature, which can be followed from Fig. 10, is the arrangement of the transformer hall parallel to the machine hall, so that there is only a short run of medium-voltage cable between each generator and its transformer bank, thus affecting a saving on cable costs.

The control room is conveniently located at one end of the machine hall. Transparent glass windows and a glass door afford a perfect view over the machine hall but protect the control room from noise.

A view of the machine hall under construction is given in Fig. 1. It is of imposing dimensions, being 80 m. long, 14 m. wide, and 25 m. high. About 30,000 cu. m. of rock had to be excavated for the machine hall alone. The ceiling is a free-span non-reinforced-concrete arch supported on side beams in places where the rock is not reliable. Along the sides of the hall concrete columns surmounted by arches support the crane runway, which carries a crane of 105 tons capacity. Light brick walls fill in the spaces between the columns.

The ventilation plant is conceived on a liberal scale. It is dimensioned to supply 50,000 cu. m. per hour, this large quantity being considered necessary to keep the station cool when it is in full production, as natural cooling through the deep rock cover cannot be relied upon.

Fresh air is drawn in through the transport tunnel by fans in a fan chamber situated alongside the erection bay (see Fig. 10) and delivered to a space behind one of the machine-hall sidewalls (see Fig. 11), whence it emerges into the upper part of the machine hall through apertures in the brick walls, seen in Fig. 11, and mixes with the air therein. Thence the air is extracted through grilles at the bottom of the sidewalls and conducted therefrom to the transformer hall, from the upper part of which it is withdrawn by fans in a second fan house and exhausted to the cable tunnel. The proportion of fresh air to circulated air can be regulated at will, and a supply of fresh air can be taken direct from the transport tunnel into the transformer hall if desired.

(To be continued)

An Experimental and Analytical Investigation of a Differential Surge-Tank Installation

By W. L. GIBSON and W. SHELSON, of the Applied Mechanics Section, Research Division, Hydro-Electric Power Commission of Ontario *

PART TWO

Theoretical Analysis of Water Hammer in System

Suitable methods, described in the literature, are available for the calculation of water hammer both in simple and complex hydraulic systems, and for the calculation of mass water flow in differential surge tanks. In order to compare the experimental and corresponding analytical results, these methods were applied to the test conditions listed previously. Some refinements and variations in the analyses, described later, were introduced either because they were found necessary to improve the accuracy of the calculated results or to assess the precision of the methods generally.

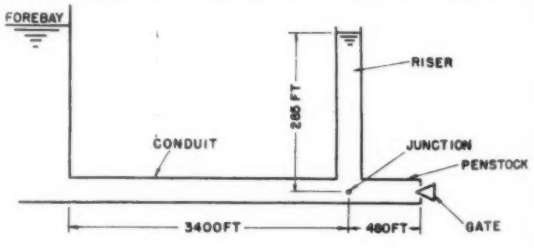
The present bases for the calculation of water-hammer pressures are due to Joukovski[7] and Allievi[8] although many others have served to interpret and extend their work. While the equations they developed can be applied in a relatively straightforward way to the problem of water hammer in simple conduits, the treatment of any complex system tends to become much more involved and lengthy due to the sub-division and interaction of pressure waves at junctions and discontinuities in the network. As a result, in the analysis of hydraulic systems, as in the analysis of any complex physical phenomenon, approximations and simplifications are often introduced. For example, in calculating the water-hammer pressure in a hydraulic conduit with a surge tank, it is common practice to consider only the water-hammer effect that would occur in a simple pipe composed of the penstock and surge riser[9].

In the present instance, however, the calculations were based on an equivalent system more closely resembling the actual installation. This was done in order to obtain a better understanding of the extent to which the performance of a full-scale installation could be predicted using the best means available, but without excessive refinements.

The hydraulic system used for the calculations is shown in Fig. 16. It consists of a uniform conduit from the forebay to the junction at the base of the surge riser, the vertical surge riser, and a uniform penstock from the junction to the turbine gates. The gate movement was assumed to take place in a series of small steps, each movement creating a water-hammer shock wave which travels up the penstock to the junction, where it undergoes a triple division, partly up the riser, partly into the conduit and partly reflected back along the penstock. The respective waves are reflected on reaching the ends of the pipes and the effects of the reflected waves are superposed on the existing pressures.

Although this problem can be handled either graphically[3, 4] or algebraically, the latter approach was chosen because both methods applied to the particular problem appeared to be too lengthy for manual solution, and only the algebraic computation could be handled directly by the available automatic digital computer. The algebraic method employed was similar in principle to the tabular methods which have been evolved by Glover[2] and Thomas[10]. In this method, several tables specifying the algebraic operations are prepared, each representing the hydraulic conditions in separate elements of the hydraulic system. Thus, in the system described here, four tables in all were used representing respectively the penstock, the junction at the base of the riser, the riser, and the conduit.

In carrying out the computations, the pressure increment due to one step of gate movement is calculated in the table for the penstock. This result is transferred to the operations table for the junction in which the pressures and flows at the junction are found. The results are then transferred to the tables for the three



PIPE ELEMENT	AREA	WAVE VELOCITY
PENSTOCK	177 SQ FT	3897 FT/SEC
RISER	143 SQ FT	3471 FT/SEC
CONDUIT	177 SQ FT	4601 FT/SEC

Fig. 16. Schematic diagram of hydraulic system used for water-hammer calculations (Wave velocities shown are approximate and values shown were chosen for convenience of computation)

*Contributed by the Hydraulic Division for presentation at the Annual Meeting, New York, N.Y., of The American Society of Mechanical Engineers.

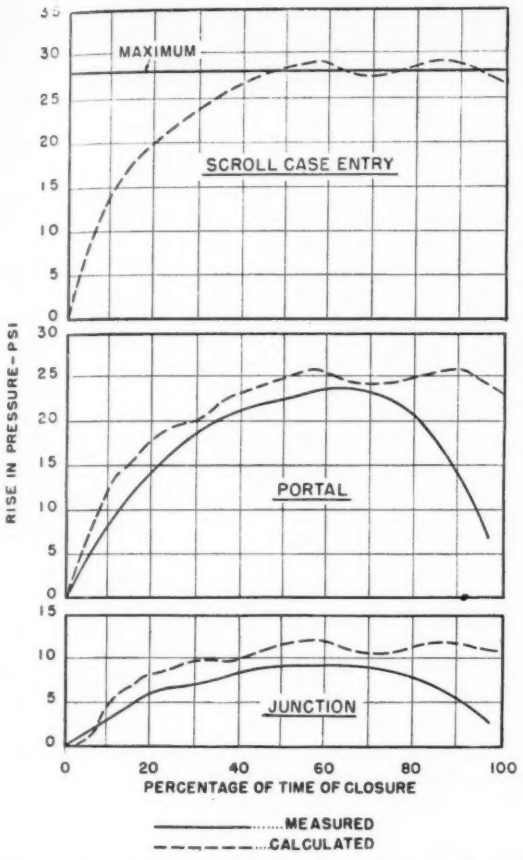


Fig. 17. Pressure change due to water hammer (Load change, 46,300 to 0 kW; turbine-gate movement, 5·1 sec.)

pipe elements and the flow conditions in each element calculated. This sequence of calculations is repeated, results being transferred from table to table in sequence and calculations done in a semi-automatic way in accordance with the routine instructions for each table. The various tables are synchronised by choosing as the step time common to all of them, a period that is the highest common factor of the reflection times of the pipes. The pipe-reflection time is the time required for a pressure wave to travel from the point where it is initiated to the point where it is reflected and back to its starting point, and is $2L/c$, twice the pipe length divided by the velocity of sound in the pipe.

In the present example, using the pipe lengths and pressure-wave velocities shown in Fig. 16, the highest common factor was 0·04105 sec. and the gate was assumed to move in a series of steps separated by this time. The number of steps required for a representative closure time of 5·2 sec. was 127, which indicates the excessive length of time required for the calculations by manual methods. Since the detailed procedures for this form of solution are adequately described in the references mentioned, a full description will not be repeated here. Of course, the solution of this problem in the automatic digital computer required a revision of the method as outlined, but the mode of solution followed the sequence noted here.

Comparison of Theoretical and Measured Pressures

The results for a gate-closure operation and for an opening operation are shown in Figs. 17 and 18, as representative examples of the theoretical solutions obtained. The measured water-hammer pressures for the three locations shown on each chart are plotted for comparison.

The measured pressures were obtained from the measurements of total pressure change minus the change in riser level, the latter being obtained from a pressure gauge near the top of the riser. The actual water hammer at the scroll cases, based on the maximum reading of a Bourdon gauge, was adjusted both for change in riser level and decrease in friction loss in the penstock.

In obtaining the theoretical curves, the following assumptions were made to simplify the computational procedure.

(a) The rate of gate movement was assumed to be linear. The oscillograph records show that the rate is not linear over the whole stroke but, in the particular cases considered, the linearity assumption is realistic as the maximum water-hammer pressure occurred before departure from linearity took place. The assumption is usual in design procedures.

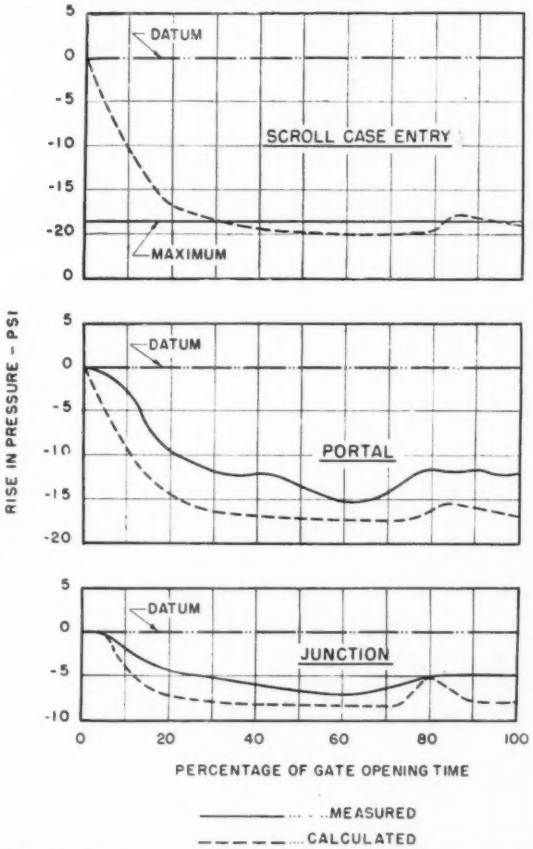


Fig. 18. Pressure change due to water hammer (Load change, 20,000 to 40,000 kW; turbine-gate movement, 2·3 sec.)

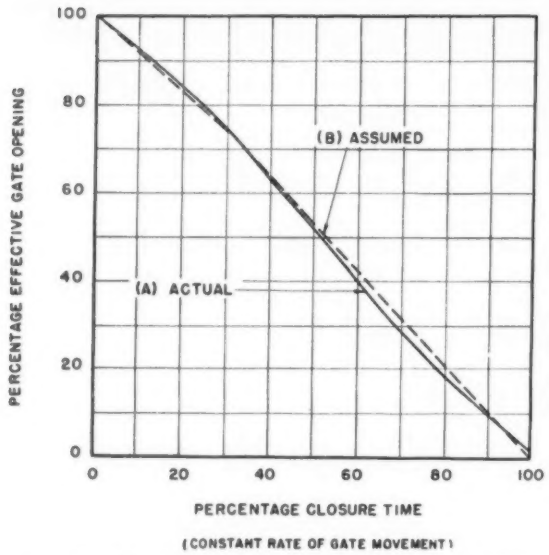


Fig. 19. Effective gate opening versus percentage closure time (A) Actual—actual gate operation based on calibration of flow versus gate position at constant head; (B) Assumed—assumed gate operation for water-hammer calculations

(b) The curve of flow against gate opening at constant head was assumed to be comprised essentially of two straight lines. Using this assumption together with assumption (a), the graph illustrated in Fig. 19 was constructed for use in the subsequent calculations of flow at any instant. The instantaneous flow was based on the percentage "effective" gate opening corresponding to the percentage of the gate closure time. The effect of the change in head was included in the calculations.

(c) The performance and operation of both turbine gates was assumed to be identical. As a result no account was taken of the Y-junction where the penstock divides to supply the two turbines.

(d) The water-hammer pressure was assumed to vary linearly between the scroll case and the base of the vertical riser. This assumption was used in plotting the theoretical curve for the water-hammer pressures at the portal.

These assumptions serve to explain some of the differences between the experimental and theoretical curves. Nevertheless, the agreement is reasonably good considering that the behaviour of the plant was deduced from a somewhat simplified mathematical equivalent.

Two Approximate Calculations of Water Hammer. One of the objectives of the investigation was to compare the experimental results with the fairly precise analytical results and also with the results calculated by approximate design methods. Two approximate methods were used; both being based on very much simplified conduit systems instead of the more accurate system used for the analytical method described earlier:

(a) In the first approximate method the conduit upstream of the surge-riser junction is considered to be so long that gate closure is complete before the return of the reflected wave; e.g., the conduit length is infinite. There is nevertheless a sub-division of pressures at the riser junction

(b) In the second approximate method the conduit length upstream of the surge-riser junction is considered to be zero. Thus the hydraulic system is replaced by a single pipe with length equivalent to the combined length of the penstock and the initial height of the water in the riser.

The results of these calculations are given in Fig. 20. As expected, the highest water-hammer pressure is obtained with the infinite conduit since the mitigating effect of the reflected wave is lost. Also, the long conduit in itself tends towards higher pressures as the gate closure time then is within the critical $2L/c$ time. Of course, the presence of the riser means that the influence of this latter consideration is greatly reduced, but is not likely absent. As the length of the conduit is reduced, the calculated pressures decrease.

For the particular hydraulic system analysed here, the maximum difference between calculated values is of the order of 20 per cent. although, in absolute terms, the difference is not sufficient to single out any particular method for design use. The best correlation between measured and calculated pressures was obtained by using the most accurate of the chosen analytical methods. It is considered that, although for this plant the water-hammer pressures are only a fraction of the total pressures and therefore the variation in results between the different methods is not important, there may be installations in which a difference of 20 per cent. in calculated water-hammer pressures may be economically important and the most accurate method should be employed. Also, since the more complex solutions can be handled quite easily with the aid of modern digital computers, there seems to be little basis today for accepting the greater uncertainties of the simpler solutions.

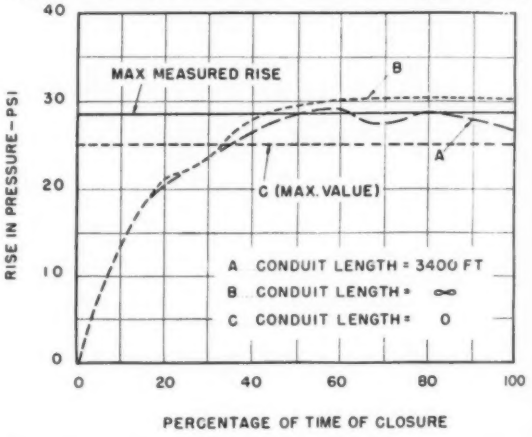


Fig. 20. Comparison of calculated water-hammer pressures and maximum measured pressure at scroll-case entry (Load change, 46,300 to 0 kW; turbine-gate movement, 5·2 sec.)

Effect of Rate of Gate Movement on Pressures. As is well known, the water-hammer pressures in a simple pipe increase with a reduction in the time of closure, up to a maximum pressure when the closure is completed within $2L/c$ sec. The same trend can be expected in more complex systems, and the rate of

closure or opening of the gates is normally limited by this consideration. To illustrate the importance of the rate of closure, the total pressure increases as measured at the tunnel portal have been plotted in Fig. 21 for three rates of closure from full load.

Effect of Changes in Velocity of Pressure Wave. The velocity of a pressure wave in a pipe filled with fluid can be determined knowing the diameter, thickness, and modulus of elasticity of the pipe, and the density and bulk modulus of compression of the fluid. In practice, however, the accurate calculation of the velocity may not be practicable, therefore the effects of approximations were investigated for the present example.

In the case of the simple pipe and within the normal range of velocities, the accepted opinion[11] is that for relatively slow closures, the value of wave velocity need not be known precisely. In the present case, where the problem is more complex and the wave velocities difficult to evaluate precisely, the importance of the accuracy of the chosen velocities was unknown. Hence, two solutions using different wave velocities were computed for one of the test conditions with relatively quick closure. The wave velocities chosen for these computations were 3,897 and 4,677 ft. per sec. in the penstock, the other velocities remaining as before. These particular values for the penstock were selected because they were convenient for computation. The results are plotted in Fig. 22 and for the two selected velocities they are almost coincident. Since the wave velocities used in the computations generally are unlikely to be in error as much as the limits in the foregoing case, the computational results are not likely to be appreciably in error due to uncertainties in wave velocities.

Theoretical Analysis of Mass Flow in a Differential Surge Tank

Comparison of Theoretical and Measured Results. As mentioned in the section dealing with the theoretical analysis of water hammer in the system, accepted methods for calculating mass flow in differential surge tanks are described in the literature[1, 12]. In carrying out the calculations for the mass flow in the surge tank, it was found convenient to use the automatic digital computer for some of the work. Although there is nothing like the benefit enjoyed in the solution of water hammer, yet the speed and economy of the machine method is advantageous when several cases have to be solved.

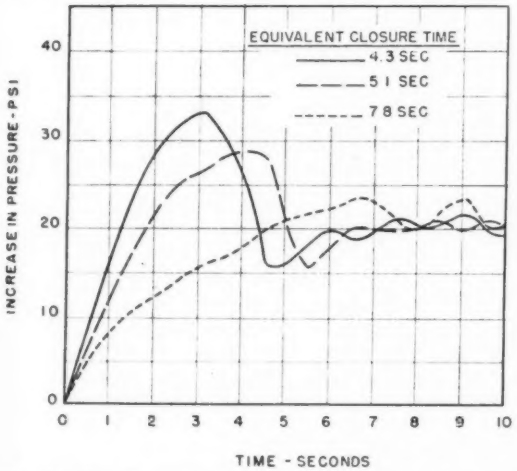


Fig. 21. Total measured pressure increase at tunnel portal for different rates of turbine-gate closure (Load change, 46,300 to 0 kW)

Some of the curves, both experimental and theoretical, of the levels in the surge tank due to closure of the gates are shown in Figs. 23 and 24. There is good agreement between the corresponding curves of levels in both the riser and the outer tank. The effective differential action of the surge tank is clearly evident in the curves, from the rapid decrease in amplitude of the water fluctuations in the riser and outer tank. In the calculations, the usual assumptions were made including linear closure of the gates, velocity head not considered, friction loss at junction and in riser neglected, etc., but water-hammer pressures as calculated were included.

Effect of Water Hammer. Standard methods for the calculation of mass flow and its effect on levels in the surge tank are in general use with apparently satisfactory results. However, when the test results at the Aguasabon generating station were being compared with the levels calculated by the usual analytical methods, it was thought that the correlation was not sufficiently close. The most likely reason for the difference appeared to be the presence of an appreciable water-hammer pressure during closure of the gates. This served to increase the rate of retardation of conduit flow and also caused a greater discharge of water through the gates during closure than otherwise would occur.

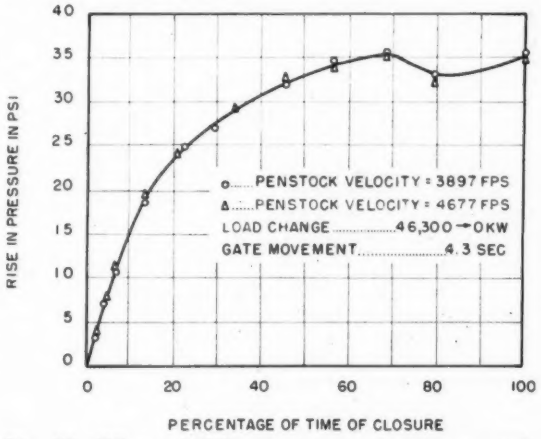


Fig. 22. Effect of different wave velocities on calculated water-hammer pressures at turbine gates

The satisfactory agreement between theory and measurement that may have been obtained by other investigators in the past was likely due to the employment of relatively slow-acting gates which created negligible water-hammer pressures or to the existence of a relatively long conduit less sensitive to transient pressures. However, when considering more responsive and rapid adjustment of turbine output, the water-hammer effect should not be overlooked as an important factor in surge-tank design and as an aid to regulation.

Both the experimental and the analytical results for surge-tank levels shown in Fig. 24 may also be com-

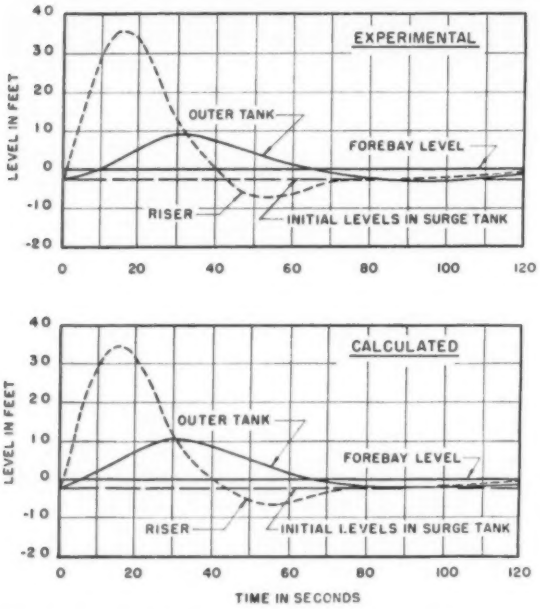


Fig. 23. Change in surge-tank levels due to gate movement (Load change, 20,000 to 0 kW; turbine-gate movement, 2·3 sec.)

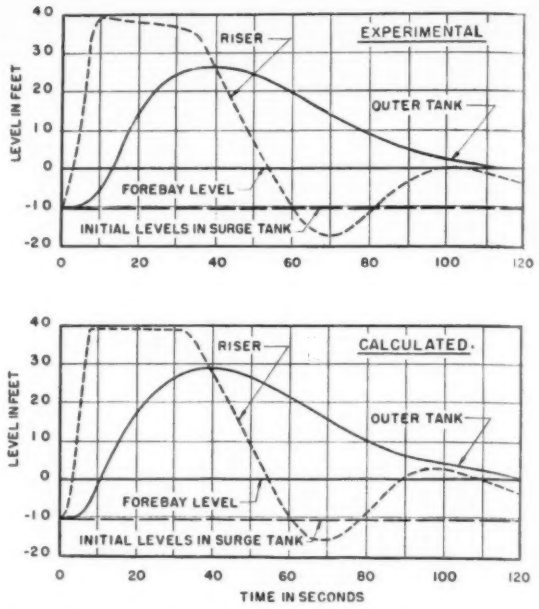


Fig. 24. Change in surge-tank levels due to gate movement (Load change, 46,300 to 0 kW; turbine-gate movement, 5·1 sec.)

pared with the calculated levels given in the lower half of Fig. 25. Fig. 25 was derived from the usual design procedure which neglects the influence of water-hammer pressures on mass flow. These results demonstrate the greater accuracy obtained by including the effect of water hammer. The simpler solution predicts a maximum level in the outer tank of 33 ft. above forebay level, whereas the addition of water hammer reduces this figure to 29 ft. Actually the measured maximum was about 26 ft. The equivalent minimum-level figures for the riser are – 20 ft., – 16 ft., and – 17 ft., respectively. Thus, consideration of the influence of the modest water-hammer pressures has provided more accurate results. This can be used to design more economical tanks. Of course, designs must be checked for slower closures which result in lower water-hammer pressures but which may require a larger surge tank than is occasioned by rapid closure.

Effect of Port Area. Much of the effectiveness of the differential surge tank is dependent on the selection of a suitable port area. The importance of this factor is well demonstrated by comparing the three curves shown in Figs. 25 and 26. The former shows the comparative results for port areas of 30 sq. ft. and 8·4 sq. ft., calculated by the usual design assumptions. The latter figure, Fig. 26, shows experimental results for the Aguasabon surge tank with the port area enlarged to 30 sq. ft. With the large port area, the oscillations tend to approximate those of a simple surge tank with inevitably slow damping, although the differential action is in evidence during the first quarter-cycle. The curve for an 8·4 sq. ft. port area shows that the surge tank is highly effective in damping out the mass oscillations.

Conclusions

The investigation showed that for the hydraulic system investigated, the surge-tank performance could be analysed quite accurately by recognised theoretical methods.

The accuracy on the mass-flow predictions were noticeably increased by taking account of the effects

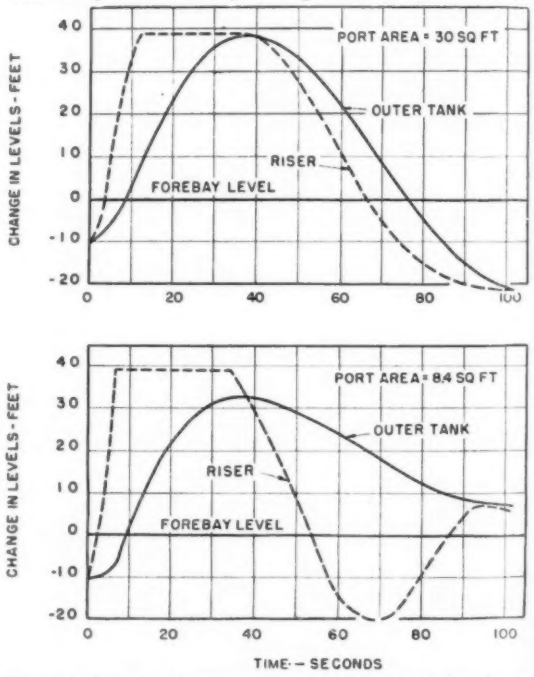


Fig. 25. Effect of port area on calculated levels in surge tank (Load change, 46,300 to 0 kW; turbine-gate movement, 5·0 sec. Water-hammer effect neglected)

of water hammer. Although it is generally recognised that the water hammer will affect the results, it is frequently omitted in ordinary surge-tank design analysis.

The water-hammer pressures were predicted with sufficient accuracy for design purposes, using approximate methods in this particular case, but the accuracy was much improved by using the full precision of the theoretical analysis. In practical problems this precision involves an enormous amount of fairly routine arithmetical work that can be very much accelerated by using a modern automatic computer. In fact a computer is almost essential if several designs or the effects of several small changes in design are being studied.

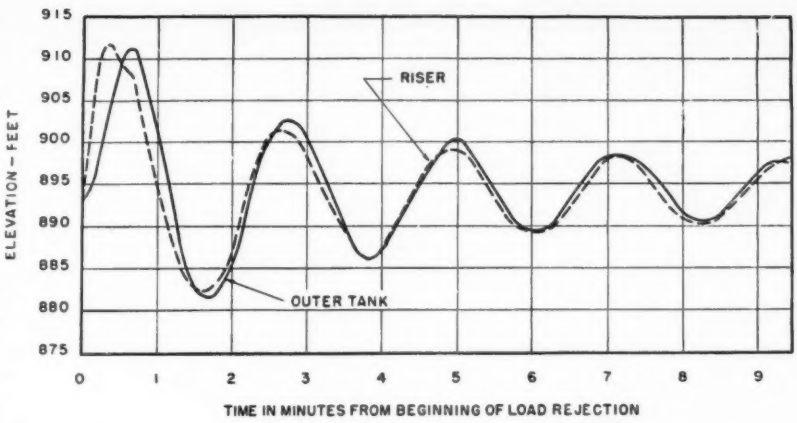


Fig. 26. Measured changes in surge-tank levels due to gate closure: port area = 30 sq. ft. (Load change, 40,000 to 0 kW; total turbine-gate time, 9 sec.)

The tests showed that in this case it was not important to know accurately the velocities of the pressure waves in the various pipe elements.

The importance of the port area in the differential surge tank was well demonstrated, and the tests showed that the Aguasabon G.S. surge tank port area of 8·4 sq. ft. was very effective as originally designed.

The tests had a direct effect on the plant in showing that fast turbine-gate operation of 5 to 7 sec. equivalent full gate time was permissible, with improved system regulation; and that the surge-tank regulation was entirely adequate to permit both machines to be operated at full gate with the possibility of full-load rejection.

In closing it should be pointed out that it is only in the last decade or so that measurements of the type described in this paper have become practicable, due to new instruments and measuring techniques having been developed for other purposes.

Acknowledgments

The authors wish to express their thanks to the Hydro-Electric Power Commission of Ontario for permission to publish this paper, and to acknowledge the co-operative effort of many associates who helped to initiate and carry out the investigation, notably Mr. E. G. Tallman and Mr. A. E. Aeberli.

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2,000,000 Dollar Cable Order

British Insulated Callender's Cables Limited, announce the award of a $2,000,000 contract by the British Columbia Electric Co. Ltd., Vancouver, for the supply of 9·9 circuit miles of single-core 230 kV oil-filled cable. The cable will be laid in ducts and will transmit power from existing 230 kV overhead lines at Kidd substation, on the north arm of the Fraser River, to distribution points situated in Greater Vancouver.

The cable will be of normal oil-filled single-core design, with a hollow copper conductor of 1,500 MCM (1·2 sq. in.) cross section. The lead-alloy sheath will have bronze-tape reinforcement and special overall anti-corrosive protection. The cable will be manufactured at the Erith Works of BICC and will be supplied in drum lengths up to 650 yards in order to reduce the number of joints needed. Joints and sealing ends will be of BICC design and manufacture. The cable will be installed under the supervision of British Insulated Callender's Construction Co. Ltd. and is required to be energised by mid-1957. It will be capable of transmitting a continuous load of the order of 280 MVA.

Early in 1954, an order valued at $3,000,000 was received by BICC from B.C. Electric for the supply of 77 miles of 138 kV gas-pressure-type cable to form an underwater cable link between the mainland and Vancouver Island.

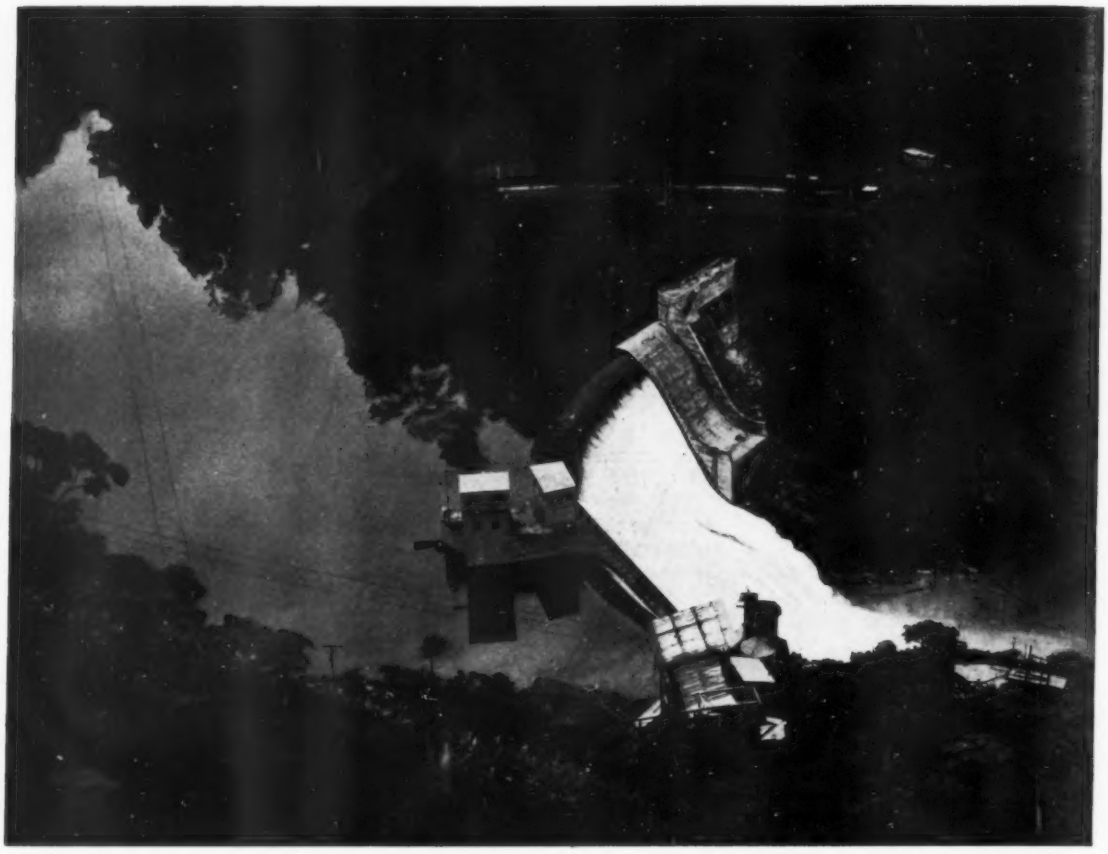


Fig. 1 Anchicaya dam as seen on completion in August 1955

The Anchicaya Power Development

This article gives a brief account of an important hydro-electric development in Colombia

By CARLOS S. OSPINA

THE most important power markets in Colombia are concentrated in and around the four largest cities: Bogotá, Medellín, Cali and Barranquilla. The first three of these are located in mountainous areas, where economic hydro sites are available, but Barranquilla, on the Caribbean, far from the Andes, has to depend upon oil-fired steam plants.

The Anchicayá project, with which this article is concerned, is located in the Pacific slope of the western range of the Andes and is designed to serve the Cali area. It was conceived and studied in 1940, but construction was not commenced until 1945, and the first stage of the project was not completed until in August, 1955. The plant was built by the Central Hidroeléctrica del Río Anchicayá Ltda., a government-controlled corporation.

The project consists of a gravity dam 60 m. high, a 1,360 m. pressure tunnel, three steel penstocks 90 m. long, and a surface power house on the river bank. It operates under a maximum head of 76·4 m., a minimum head of 67 m., and a normal minimum head of 71 m. A total capacity of 64 MW will be installed in four units. Two 12 MW units have already been erected, and two 20 MW units will be put into commission in 1956.

The Anchicayá River has a drainage area, at the dam site, of about 750 sq. km. Its average flow is 90 cu. m. per sec., the minimum flow that has been recorded is about 20 cu. m. per sec., and the maximum recorded flow has been about 1,800 cu. m. per sec. This river has the typical characteristics found in the streams flowing from the western range of the Andes

through a forest area, experiencing a rainfall ranging from 5,000 mm. to 8,000 mm. per annum.

Fig. 1 gives a view of the dam. It is a concrete arch gravity structure, 203 m. long at the crest, with a maximum height of 60 m. and 42 m. maximum width at the base. The spillway, located over the crest of the dam, is of the ogee type, with a ski jump at the lower end. There is a centre section 111 m. long, with a crest elevation of 194·4 m. and a lip elevation of 163·3 m. The side sections each have a length of 30 m., a crest elevation of 195·2 m. and a lip elevation of 175 m. The discharge capacity, with a head water level of 201 m., is 5,700 cu. m. per sec. The elevation of the abutments is 201 m.

Between elevation 194·4 m. and elevation 189 m., the reservoir has a normal capacity of 1·5 million cu. m. The maximum drawdown level, to elevation 185 m., will increase the reservoir capacity to 2·3 million cu. m. This small reservoir is to be used only for pondage.

Two 5 ft. × 6 ft. sluiceways are provided and have a sill elevation of 154·5. These sluiceways are protected by trashracks, and the high-pressure gates are electrically operated.

The tunnel intake, which is between elevations 169 m. and 184 m., is located in the same reinforced-concrete structure as the sluiceway, and is provided with trashracks. The pressure tunnel is 6·3 m. in diameter, is circular in section, and is lined with concrete throughout its length. The concrete lining has a minimum thickness of 25 cm. where no reinforcement is required, and is 35 cm. thick where reinforced. Reinforcement was used only at short sections where the rock was not sound. The tunnel was driven through diorite and schist, generally of good quality, but poor rock was encountered at the outflow end, where the surge tank is located. In this area, decomposed schist gave a good deal of trouble and required careful precautions in constructing the underground structures to ensure perfect stability.

The surge tank is of the differential type, the larger chamber being about 16 m. in diameter, and the small chamber, which acts as a riser, 6 m. in diameter. The

Fig. 2. The dam site looking downstream, February 1954

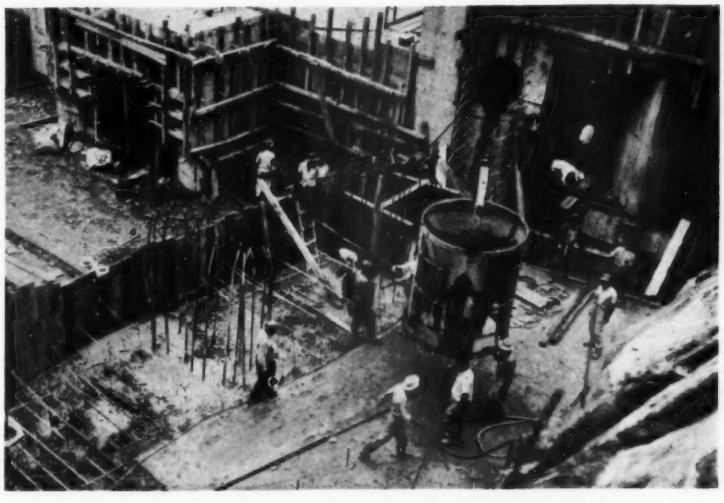


Fig. 3. Placing concrete in the intake tower

Fig. 4. Anchicaya power station, showing the two 12 MW units

connection between the riser and the pressure tunnel has a venturi construction, 5 m. in diameter, to increase stability for minor oscillations. The valve house is located at the tunnel portal at elevation 159. It consists of a concrete structure which houses three butterfly valves. Just upstream from the valve house is a steel trifurcation, the first branch, 3 m. in diameter, feeding the two units already installed.

Power House

The power house is of reinforced-concrete construction and at present is equipped with two 17,100 h.p. S. Morgan Smith vertical-shaft Francis turbines, operating at 257 r.p.m., coupled to Westinghouse generators having a capacity of 15,000 kVA at 0·8 power factor.

The two new units will comprise 32,000 h.p. 257 r.p.m. Neyrpic turbines and 25 MVA Brown-Boveri generators.

The substation is located behind the power house, the transformers being of the outdoor oil-immersed self-cooled three-phase type, with a rating of 11,250-15,000 kVA and will step up the voltage from 6,600 to 115,000 V.

For the new generating sets the transformers will consist of six single-phase 8,333 kVA units. The transmission line is 52·5 km. long, supported on 98 steel towers of the double circuit type, and operates at a voltage of 115 kV. The conductors are 300,000 circular mills, 26 × 27 ACSR double-circuit, with double ground wire made up of $\frac{3}{8}$ in. seven-strand high-strength steel.

The immediate programme to increase generating capacity for this area considers, in addition to the two new units at Anchicayá, the installation of two 12·5 MW steam generating units at Yumbo, near Cali, and the construction of a large hydro-electric plant on the Calima River, about 70 km. north of Cali.

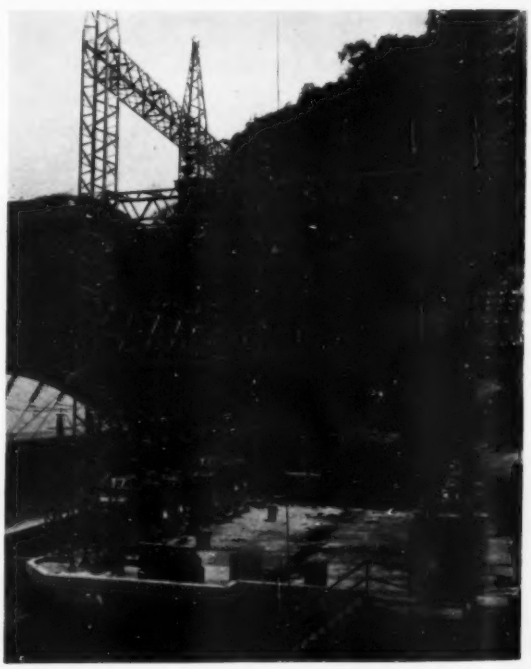


Fig. 5. The main transformer yard behind the power station

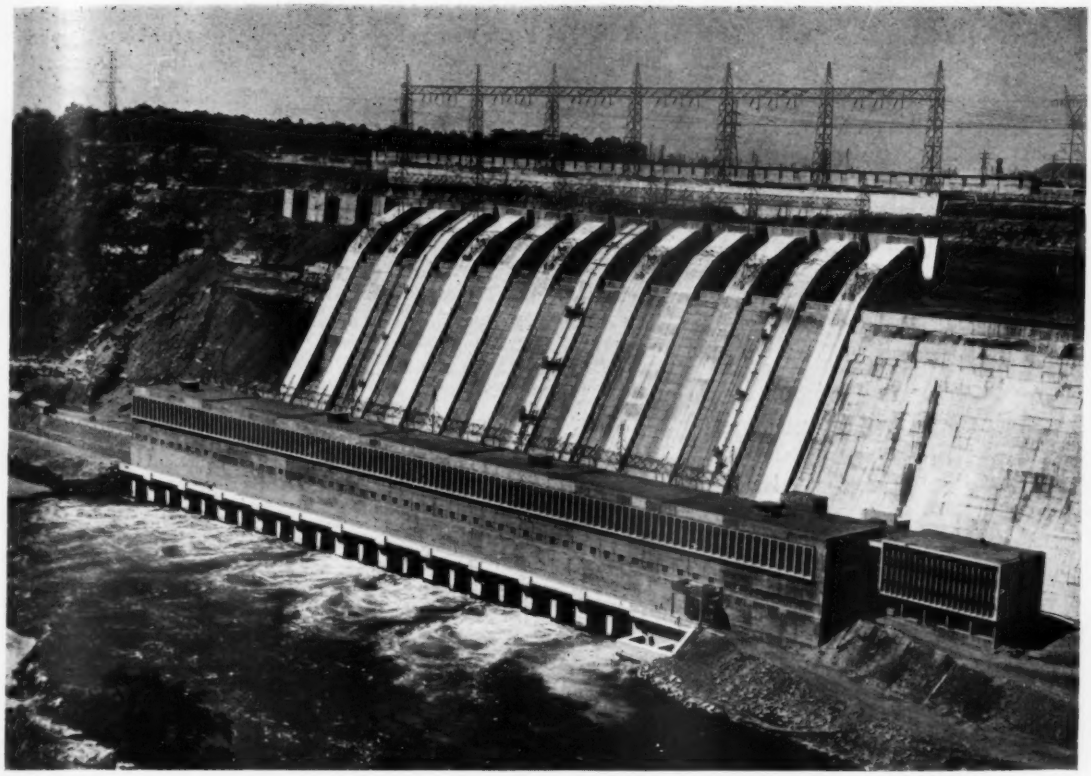


Fig. 1. A recent view of Sir Adam Beck No. 2, Niagara

Hydro-Electric Progress in Canada

The Water Resources Branch, Department of Northern Affairs and National Resources, Canada, has issued its customary annual review* of water-power progress in Canada

KEEPING pace with the expansion of industrial activity throughout Canada and also with the increasing demand for power from commercial and domestic sources, construction of power plants proceeded vigorously in 1955. Although somewhat lower than the average increase registered in the last five years, the appreciable amount of 839,630 h.p. of new capacity was added in 1955 to the total of hydro-electric generating stations in the country. Construction was also active on a number of other projects, comprising about 1,000,000 h.p. to come into operation in each of the years 1956 and 1957, while preliminary construction or planning covers about 4,000,000 h.p. for later years. The greatest single addition to capacity in 1955 was that of 525,000 h.p. at the Sir Adam Beck-Niagara Generating Station No. 2 of the Ontario Hydro-Electric Power Commission, the remainder of the increase being in comparatively small projects well distributed across the country. The total installed capacity of water-power plants in Canada is now listed at 17,531,536 h.p. which, however, represents only about 27 per cent. of total resources.

In addition to hydro-electric development, the building of new thermal-electric plants and extensions proceeded at a good rate. In the field of power distribution, new main transmission lines were completed or were under construction, substation capacity was increased, and rural distribution lines were extended in many parts of the country.

A review of the year's activities in central-station construction and in distribution facilities is given below by provinces.

British Columbia

Although the amount of new capacity which was completed during the year was small, hydro-electric

* Bulletin No. 2476. "Hydro-Electric Progress in Canada, 1955." Obtainable free of charge on application to the Director, Water Resources Branch, Department of Northern Affairs and National Resources, Ottawa.

construction was very active in British Columbia with work under way on several new projects and on additions to existing plants.

The British Columbia Power Commission completed the redevelopment of the Puntledge River site near Courtney, Vancouver Island, the plant comprising a 35,000 h.p. turbine under 340 ft. head driving a 25,000 kW generator; operation is by remote control from the John Hart plant on Campbell River. Also completed was the development of 5,500 h.p. on the Spillimacheen River comprising two reconditioned units each of 1,250 h.p. with 900 kW generator and a new unit of 3,000 h.p. with 2,200 kW generator; the available water supply is being increased by the diversion of Bugaboo Creek into the Spillimacheen River. The Commission began construction in May on the development of Ladore Falls, Campbell River, to commence operation in 1956 of two units each with a 35,000 h.p. turbine operating under a head of 122 ft. and driving a 30,000 kW generator, and ultimately a third similar unit; the plant is to be of the outdoor type and will be remotely controlled from the John Hart station. In association with the Ladore Falls project, preliminary construction was undertaken on an earthfill storage dam 160 ft. in height and 1,800 ft. in length at the outlet of Upper Campbell Lake and of a power plant of two units each of 42,000 h.p. under 140 ft. head with initial operation in 1957. On the mainland, work was commenced on the installation of a third unit of a 16,500 h.p. turbine with 11,250 kW generator for operation in 1956 in the Whatshan River plant near Needles. Surveys and investigations were carried out covering developments on the Quesnel and Murtle Rivers, but no decision on construction has been made. During the year, the 33 kV transmission line from Spillimacheen to Golden was completed and work was commenced on five miles of double-circuit 138 kV line from Ladore Falls to the John Hart station and on a 27-mile 60 kV line between Kamloops and Savona.

The British Columbia Electric Co. Ltd. continued the construction of a development on Seton Creek near Lillooet to be completed in 1956; the plant contains a single turbine of 58,500 h.p. under 147 ft. head driving a 42,000 kW generator; the dam has been completed and good progress made on the 12,000 ft. power canal and on the powerhouse. Construction also was under way on a development of 190,000 h.p. in two units for 1957 operation, involving the diversion of water from the Cheakamus River near Garibaldi to the Squamish River by means of a dam at the outlet of Daisy Lake and an 18 ft. diameter tunnel seven miles in length; dam-site clearing has been completed and tunnel driving about one-third completed. At the Bridge River development, the Lajoie storage dam has been raised an additional 30 ft. to the overall height of 282 ft. which provides 570,000 acre-feet of storage. The Company continued to extend its transmission system with a 345 kV line under construction from Creekside to Rosedale via Lillooet and with a connection to the line from the Wahleach plant which is being raised to 345 kV. A 120 kV submarine cable, to interconnect the Vancouver Island network with the mainland, is being manufactured in England and

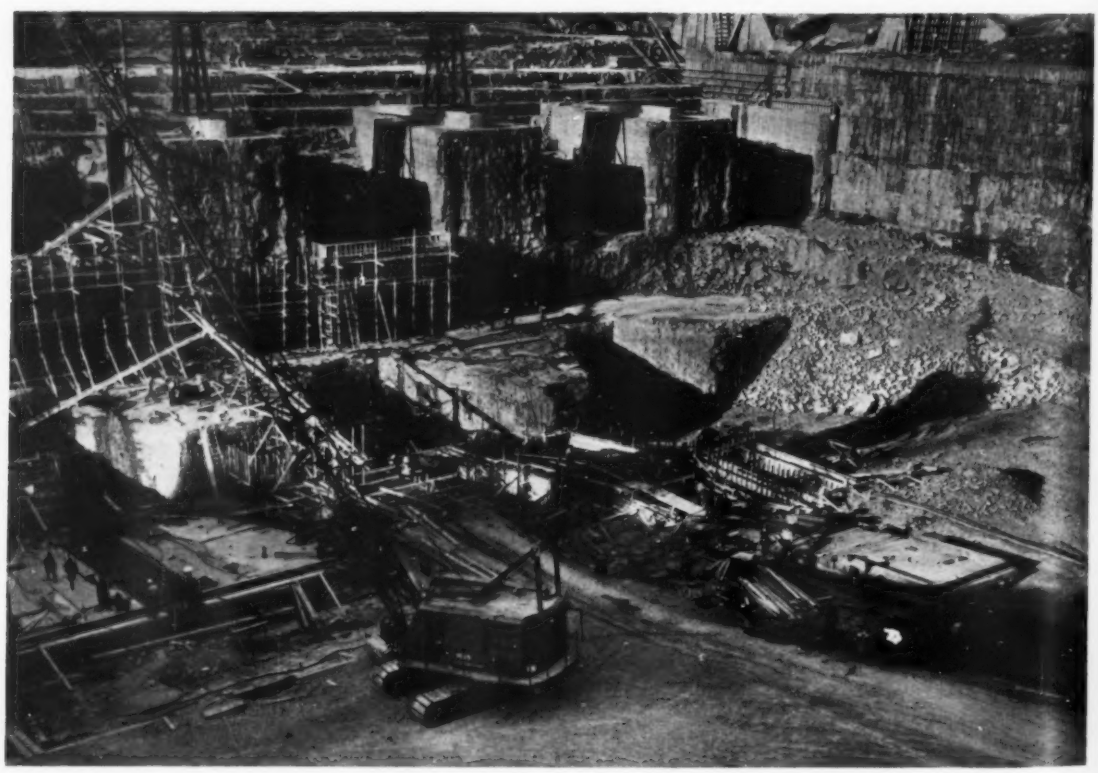


Fig. 2. Power-house phase of the Niagara pumping-generating project

Fig. 3. Cofferdams for the Long Sault Dam, St. Lawrence Power Project

will be laid in 1956; it will be connected to a 132 kV line at each end. A new substation of 50,000 kVA capacity was completed in Vancouver. The Company also has taken over from the British Columbia Power Commission its distribution system in the Sechelt Peninsula and the Clowhom Falls plant of 4,000 h.p.; preparations are being made to extend the system by a 132 kV line to Powell River which will involve crossing Jervis Inlet with a clear overwater span of 10,100 ft. About 12,000 farms in the Fraser River Valley are served by the Company.

The Aluminum Company of Canada has under installation in its Kemano plant a fourth unit of 150,000 h.p. for operation early in 1956. Also, orders have been placed and preparations made for a fifth unit to come into operation late in 1956 or early 1957, which will bring total capacity to 750,000 h.p. The installation by 1959 of a further three units is in active prospect.

The Northern British Columbia Power Company has rebuilt its Shawatlans hydro-electric plant at Woodworth Lake which was destroyed by fire last year. The new powerhouse is of reinforced concrete and contains a 2,140 h.p. turbine with 1,650 kW generator, the head being 218 ft.

The Powell River Company Limited has work under way on a project to divert water from the upper Theodosia River into Powell Lake which will increase the firm power output of its hydro-electric plant by about 2,000 kW.

Northwest Power Industries Limited is investigating the Nass River, which empties into Portland Inlet, with a view to the development of about 450,000 h.p., with water storage on Bowser and Meziadin Lakes. If development proves to be economic, construction may be undertaken in 1957. It is understood that such a development would cause delay in the construction of the first stage of the Yukon-Atlin-Taku project as planned by the Company and referred to hereunder.

Yukon Territory

The Yukon Hydro Co. Ltd. completed its new plant on McIntyre Creek, near Whitehorse, comprising an 800 h.p. turbine and 750 kW generator. The Company now has a hydro-electric capacity of 2,190 h.p. in two plants and diesel capacity of 610 h.p.

Northwest Power Industries Limited continued investigations towards the storage of water in lakes in the headwaters of the Yukon River and its diversion through the Coast Mountains to realise a high head at a point near tidewater in the Nakonake valley in northern British Columbia. No commitments have been made on construction of this Yukon-Atlin-Taku project, but preliminary plans envisage the development initially of 80,000 h.p. and ultimately of more than 4,000,000 h.p. The proposed industrial site would be on the Taku River in British Columbia.

Alberta

In further development of the power resources of the Bow River basin, Calgary Power Limited completed two new projects on the Kananaskis River; the Pocaterra plant, above the mouth of Pocaterra Creek, comprises a single unit operating under 210 ft. head

with an 18,400 h.p. turbine and 15,000 kVA generator; the Interlakes plant, located farther upstream between Upper and Lower Kananaskis Lakes, comprises a 6,900 h.p. turbine under 127 ft. head driving a 5,600 kVA generator. The Company is planning further additions to its Spray Lakes, Rundle, and Cascade plants, but no construction schedule has been set up; investigations also are continuing towards a development on the North Saskatchewan River about 15 miles south-west of Brazeau station. The transmission network was increased by 80 miles of line at 132 kV, 38 miles at 66 kV, and 243 miles at 22 kV. A total of 25,060 farms is being serviced by the Company, out of the overall total of 34,000 electrified farms in the province.

Northland Utilities Limited is proceeding with the installation of an additional Kaplan turbine of 1,000 h.p. in its Astoria plant near Jasper for operation in 1956. Preliminary studies of a site on Heart River were continued. A 90-mile 23 kV line from Grimshaw to Manning was built during the year.

Manitoba

The Manitoba Hydro-Electric Board completed the development of the remaining four units each of 10,000 h.p. in its McArthur Falls plant on the Winnipeg River, the total capacity being 80,000 h.p. The Winnipeg River in Manitoba is now fully developed, and if it is considered to be more economic than a thermal plant, the next hydro-electric project to be undertaken probably will be at Grand Rapids, at the mouth of the Saskatchewan River at the north end of Lake Winnipeg, where surveys and investigations were carried out during the past year covering a possible installation of 460,000 h.p. A double-circuit 110 kV line from McArthur Falls to Transcona was completed in June and the Transcona substation has been rebuilt.

The City of Winnipeg carried out major repairs to the dam at its Pointe du Bois generating station on the Winnipeg River. Under an agreement with the province, the City of Winnipeg hydro-electric system becomes the sole distributor of electricity within the city and will continue to operate its two plants on the Winnipeg River and its thermal station. The Manitoba Hydro-Electric Board will operate other plants and be responsible for the development of further adequate supplies of power.

Electrical distribution throughout the province, except for the City of Winnipeg, is carried out by the Manitoba Power Commission which extended its transmission network by 58 miles of line operating at 115 kV., 20 miles at 66 kV., 83 miles at 33 kV., 17 miles at 6·9 kV., and 288 miles of rural lines; also 55 miles of line was raised from 33 kV. to 66 kV. An additional 700 farms were given service in 1955 and

Fig. 4. Bersimis machine hall, which will house eight 150,000 h.p. sets

Fig. 5. Lac Cassé portal which will supply the Bersimis station

more than 42,000 farms are now connected to the system.

Ontario

The Hydro-Electric Power Commission of Ontario vigorously continued its rapid expansion of generating capacity, with major projects under way on the Niagara and St. Lawrence Rivers and with moderate-sized plants under construction in the north-western part of the province, as outlined below:—

Sir Adam Beck-Niagara Generating Station No. 2. At the beginning of 1955 the power house was essentially completed and seven generating units were in operation. The remaining five units were brought into service during 1955, the twelfth in August. The installed capacity of the twelve turbines is 1,260,000 h.p.

As work on the main project was brought to completion, the emphasis in construction shifted to the pumped-storage scheme associated with it. Six reversible pump-turbines are to be installed in a pumping-generating station located about half a mile from Sir Adam Beck-Niagara Generating Station No. 2 and just to the north of the recently constructed canal leading to it. The turbines will pump water from an offtake canal communicating with the new canal into a reservoir some 700 acres in extent and having a usable capacity of about 16,000 acre-feet. When operated in reverse by water returning from the reservoir each unit will have a capacity of 47,000 h.p. at maximum discharge of 5,600 cusecs and under full reservoir head of 85 ft. The first unit is scheduled for service at the end of 1956 and all units will be in operation by September 1957.

Construction of the dyke forming the storage reservoir went ahead rapidly during the summer and fall of 1955 and by the end of the year 75 per cent. of this work was completed. Excavation work for the offtake canal and for the pumping-generating station was finished, and the first concrete for the station itself was placed in August 1955.

Niagara River Remedial Works. The addition of the above generating facilities was made possible under the terms of the Niagara Diversion Treaty of 1950 which permits some flexibility in the diversion of water for power purposes. The fulfilment of these terms, however, required the construction of certain remedial works which was undertaken jointly by Canada and the United States. The works include a control structure on the Canadian side of the river about a mile upstream from the falls, the excavation of certain river-bed areas, and the placing of fill in other areas on both flanks of the falls. This work of excavating and placing of fill was completed on the Canadian side by Ontario Hydro in 1955.

The 1,550 ft. control structure, which has been under construction since December 1953, will consist of 13 individually operated bascule-type gates mounted between concrete piers. The structure is be-

ing built in six stages, each stage involving cofferdamming, concreting, and the erection of gates. The cofferdam around the first pair of gates was removed in June 1955 and the cofferdam around the second in September. By the end of May 1956 another three gates are expected to be in operation, and by August 1957 the remaining three stages of the work, involving the erection of the last six gates, should be finished.

St. Lawrence Power Project. The St. Lawrence Power Project is the last major hydraulic site in southern Ontario. Construction of the development, which is located in the International Rapids Section of the St. Lawrence River, is being carried out jointly by Ontario Hydro and the Power Authority of the State of New York. The main features of this project include two adjoining power houses forming an integral part of the gravity-type dam structure, two control dams, and dykes to contain the headpond. The power-house structure, bisected by the International Boundary, will span the north channel of the river at the eastern end of Barnhart Island. A dam spanning the south channel at Long Sault Rapids will control the level of the headpond; a dam at Iroquois Point will regulate flow from Lake Ontario.

Ontario Hydro is responsible for the construction of the Canadian half of the power-house structure, for building some three miles of dyke extending upstream from the power house, for improving certain river channels as required, and for the rehabilitation of the areas to be flooded on the Canadian shore. This rehabilitation will include the re-establishment in new locations of approximately 6,500 people, and the relocation of some 40 miles of railway line and about 35 miles of highway. Good progress was made during early 1955 in the construction of the cofferdams for dewatering the power-house area, and in July excavation was begun at the power-house site. Convenient access without interference to shipping was provided by two tunnels under the Cornwall canal and a Bailey retractable bridge over the canal. Meanwhile, work was also undertaken for the construction of the dyke at Cornwall, for the relocation of the Canadian National Railways line, and for the construction or relocation of transmission-line facilities. In September full-scale rehabilitation work was under way in the village of Iroquois, which is in the area to be flooded. At the end of 1955 nearly 3,000 persons were engaged on the project.

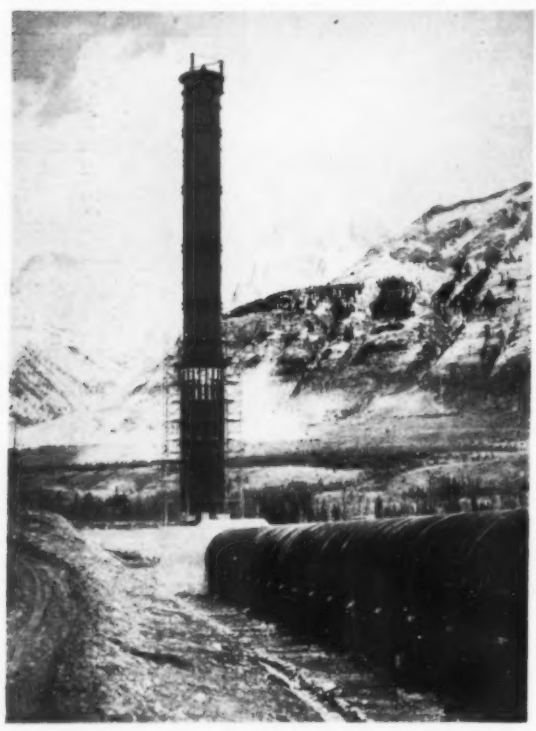


Fig. 6. Standpipe, 139 ft. high, for Calgary's 18,500 h.p. Pocaterra plant

The Long Sault dam and the Iroquois dam are being constructed under the supervision of the Power Authority of the State of New York. Present plans call for the closure of the Long Sault dam to establish the headpond in 1958. Ontario Hydro's 16 generating units are scheduled to be placed in service in the period 1958-1960. The turbines will have a total installed capacity of 1,200,000 h.p.

Manitou Falls Generating Station. This generating station, located on the English River some 20 miles below Ear Falls, is scheduled for initial service in April 1956. Present plans call for the installation of four units, each with an installed turbine capacity of 18,500 h.p. Provision is being made, however, for the possible later addition of a fifth unit. Some preliminary work was done during 1954, but with the dewatering of the power-house area early in 1955, actual construction was begun. The auxiliary and wing dams were completed, and by the end of 1955 the power-house structure was approaching completion. Prefabricated aluminium panels are being used instead of reinforced concrete to form the exterior walls of the superstructure; this is the first time the Commission has used this type of construction for a power house. The substructure for all four units was almost finished; the erection of two turbines was completed at the end of the year, and the installation of the generators for these two units will begin early in 1956. Installation of the power transformers and electrical control equipment will be carried out at the same time. All four units are expected to be in service in July 1956.

Whitedog Falls Generating Station. In August 1955 the Commission decided to undertake the development of Whitedog Falls in north-western Ontario. The generating station will be located on the Winnipeg River about 12 miles east of the Manitoba boundary and 30 miles north-west of Kenora. Three generating units, which will have a combined capacity of about 81,000 h.p., will be installed. Before construction can be started, a 16-mile access road must be built from a point on the Canadian National Railways line near Minaki. Plans call for the completion of this road by September 1956, while the generating station itself is scheduled for service in December 1957.

Transmission Network. During 1955 there were increases in mileage of transmission and rural distribution lines in service as follows:

230 kV lines	14 circuit miles
115 kV lines	267 circuit miles
13-44 kV lines ...	74 circuit miles
Rural distribution lines	1,269 circuit miles.

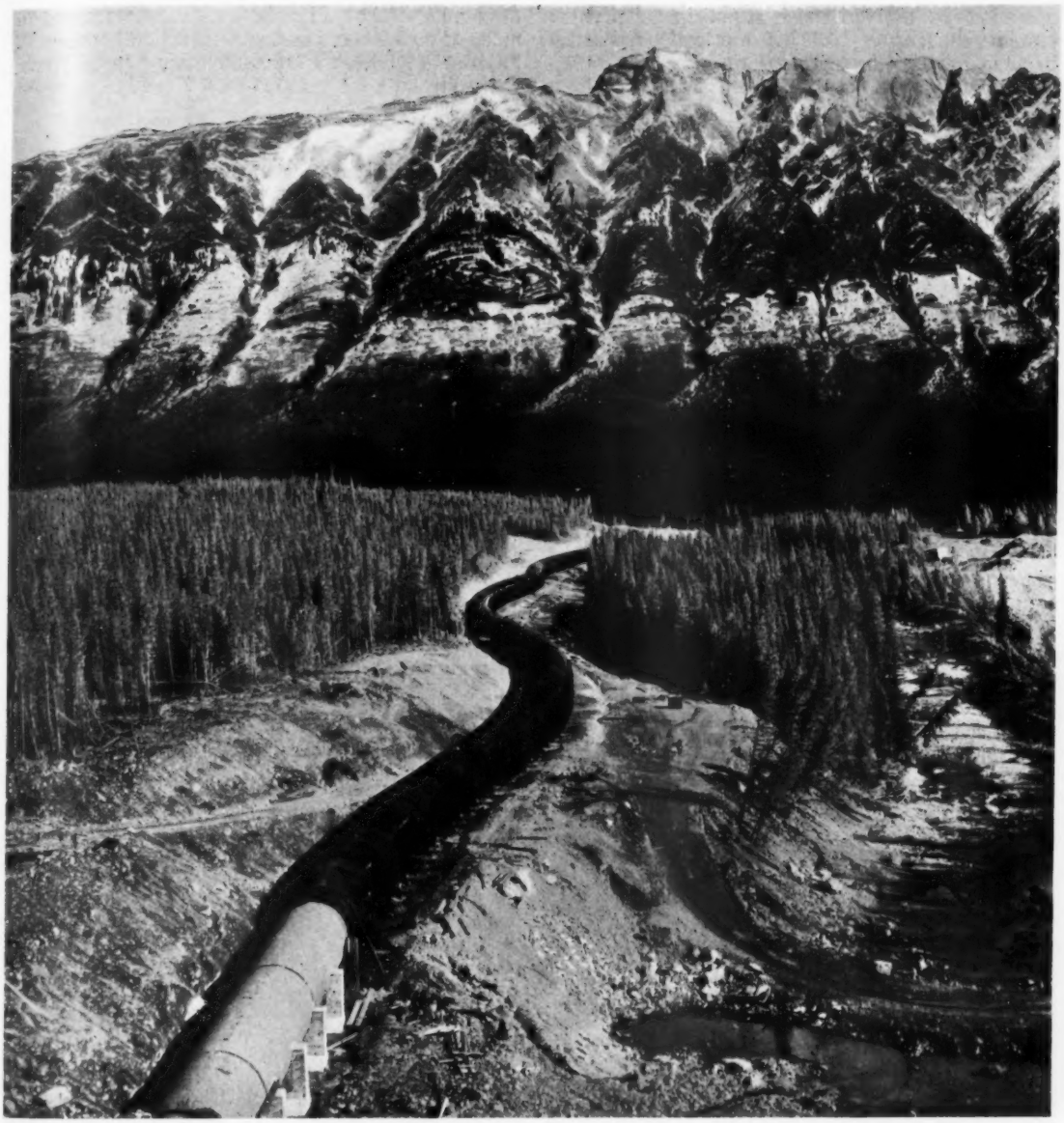


Fig. 7. Woodstave pipeline from Lower Kananaskis Lake to Pocaterra station

It is estimated that by the end of 1955 the total number of rural customers served by the Commission will be approximately 416,100, including about 138,400 farm customers.

Aside from the activities of the Commission, the Ontario and Minnesota Power Company completed the modernisation of its plant on Rainy River involving an increase in capacity of 650 h.p. by runner replacement.

Quebec

The intense programme of hydro-electric construction, which has been proceeding in Quebec during recent years, made important strides during the year to keep pace with the rising demands of a rapidly expanding industrial economy. Mining developments in Chibougamau and other districts, and surging growth in the aluminium industry, continue to foster additional development of the vast resources of the province.

The Quebec Hydro-Electric Commission made good progress on its Bersimis River project. The building of the main dam at the outlet of Lake Casse is nearing completion, the driving of the 31 ft. diameter 7½-mile tunnel and the excavation for the underground power house have been completed, and tunnel lining and excavation for the surge tank are well advanced. The first three units each consisting of a 150,000 h.p. turbine and a 138,000 kW generator are under installation and are expected to come into

operation late in 1956 and it is anticipated that the ultimate capacity of 1,200,000 h.p. will be installed by 1958. Surveys and investigations have been underway at Bersimis No. 2 site 23 miles downstream from No. 1, and it has been announced that development of about 650,000 h.p. will be undertaken immediately. The immediate development of a storage reservoir on the Manicouagan River also has been announced; this will permit an additional installation of about 150,000 h.p. at the First Falls plant of the Manicouagan Power Company by 1957 and it is anticipated that the Second Falls site may be developed by 1960.

On the upper Ottawa River at Rapid II, the Commission has under installation a third unit of 16,000 h.p. which will come into operation in 1956. Provision has been made for a fourth unit to bring ultimate capacity to 64,000 h.p. At Beauharnois on the St. Lawrence River, dredging of the intake canal is being continued and the Commission plans to start construction of Beauharnois No. 3 plant in the immediate future. Plans call for an initial installation of about 450,000 h.p. and an ultimate capacity of about 675,000 h.p. The Commission also is pressing its studies of the first-stage Lachine development of 900,000 h.p. In the transmission field, a 146 mile 154 kV line to serve the Chibougamau district was completed in May and good progress has been made on the double-circuit 300 kV line from Bersimis to Quebec and Montreal: also, the 31½ mile submarine cable under the St. Lawrence River between the Manicouagan Peninsula and Les Boules was restored to operation in November and power now is being transmitted from the plant of the Manicouagan Power Company to the Gaspe district.

The Shawinigan Water and Power Company completed the installation of an additional unit in each of three plants on the St. Maurice River, 44,500 h.p. at Rapid Blanc, 65,000 h.p. at La Trenche and 49,000 h.p. at La Tuque, for a total increase of 158,500 h.p. The transmission system was extended by 81 miles of line operating at 220 kV, 37 miles at 110 kV and 9 miles at 60 kV. The Company reports that it is now serving approximately 43,000 farms.

The Gatineau Power Company has under installation for operation early in 1956 a new 60 cycle 47,000 h.p. unit in its Paugan Falls plant on the Gatineau River, to bring total capacity to 285,000 h.p.

The Northern Quebec Power Company Limited completed the installation at their Quinze Rapids plant on the upper Ottawa River of an additional unit of 34,500 h.p., to bring the total capacity to 119,000 h.p.

Eastern Smelting and Refining Company Limited began preliminary construction during the past summer on a development on the Chicoutimi River about one-third of a mile upstream from the existing plant of Price Brothers and Company. The new plant will comprise a 42,000 h.p. turbine under 280 ft. head driving a 40,000 kVA generator and is scheduled for 1957.

Extensions to transmission systems were made by other companies. Lower St. Lawrence Power Company expected to complete by the year's end a 69 kV line from Rimouski to Trois Pistoles, together with a 5,000 kVA substation; its rural distribution system serves about 9,500 farms. Saguenay Transmission Company built 20 miles of 154 kV line from Dolbeau to St. Felicien. Quebec Power Company completed three miles of 24 kV line between substations and 26 miles of 66 kV were under construction between St. Pascal and Riviere du Loup. Southern Canada Power Company built 12 miles of 48 kV line.

New Brunswick

The New Brunswick Electric Power Commission has construction under way on the Beechwood site on the Saint John River to comprise initially two turbines each of 45,000 h.p. under 60 ft. head and with provision for a third similar unit. The relocation of a two-mile reach of the Canadian Pacific Railway has been completed and the required highway relocation is well advanced. Initial operation is scheduled for the spring of 1958. During the year the transmission system was extended by 60 miles of 138 kV line from Grand Lake to Moncton and by 42 miles of 69 kV line in other districts.

Nova Scotia

The Nova Scotia Power Commission completed in September its 6,240 h.p. development on the Mersey River at Lower Great Brook, comprising two units, each with a 3,120 h.p. Kaplan turbine under 22 ft. head and a 2,500 kVA generator. Construction has been undertaken on a development on the Bear River at Bear River station, the installation to be of 5,300 h.p. under 142 ft. head, with operation scheduled for early 1957. Two additional sites are under investigation, one at Wreck Cove and the second at Bad Falls on the Tusket River. During the year moderate extensions were made to the transmission system and a 47 mile 66kV line joining the Big Falls and Gulch generating stations is under construction. A new 5,000 kVA station was built at Lower Great Brook.

Newfoundland

Union Electric Light and Power Company Limited was expecting to complete in December a new plant on the Trinity River comprising a 2,000 h.p. turbine under 260 ft. head, driving a 1,800 kW generator, with a second similar unit to be added in 1956. Transmission lines of 46 kV capacity were built between Lockston and Georges Brook, 33 miles, and Lockston to Port Union, 15 miles; also 33 miles Lockston to Clarenville were under construction.

The United Towns Electric Company has under construction for operation in late 1956 an installation of 5,600 h.p. under 275 ft. head on New Chelsea Brook near New Chelsea. Investigations also have been made covering a small plant at Pitmans Pond. Firm capacity of the Topsail plant has been increased by the diversion into the storage reservoir of part of Manuels River drainage. Transmission lines were extended by 17 miles of 66 kV line from Bay Roberts to Avondale and 15 miles of 13·8 kV line, Cape Broyle to Renews.

Anglo - Newfoundland Development Company Limited increased the capacity of its plant at Grand Falls on the Exploits River by 4,000 h.p. by replacement of runners, total capacity now being 64,000 h.p.

Bowater Power Company Limited has under consideration a plant of 12,000 h.p. in two units under 565 ft. head on Corner Brook River.

NOTE. Figs. 1-3 are by courtesy of Ontario Hydro, Figs. 4 and 5 by courtesy of Hydro Quebec, and Figs. 6 and 7 by courtesy of Calgary Power Ltd.

Book Reviews

An Introduction to Fluvial Hydraulics. By Serge Leliavsky. Constable & Co. Ltd., 10 and 12 Orange Street, London, W.C.2. 257 pp. Numerous illustrations. Price 30s. net.

Many of our readers will doubtless welcome the inclusion in this journal of a review of this book on the flow in natural rivers carrying a "charge" of suspended sediment and causing a continuous movement of the erodible material forming their bed and banks; for the connection between the development of water power and river control is present in most schemes, and the combination of hydro-electric schemes with those of navigation or of water supply for irrigation, industrial or domestic purposes, is becoming increasingly frequent.

His background gives Dr. Leliavsky exceptional qualifications for the task he has set himself, of writing a short but comprehensive survey of the published data, the methods used to obtain them, and the theories put forward for their explanation. After being Head of the Hydraulic Section of the team of engineers engaged on the design and construction of the great Dnieper river-control and hydro-electric barrage in Russia, he has successively occupied the most senior positions in various Egyptian irrigation-design and Nile-control departments and, simultaneously, been a Professor at the Engineering School at Giza.

In the present work the author draws the distinction between the two methods of approach to his problem which have been followed so far: one is aimed at finding the physical causes and mechanisms of erosion, bed-load movement, saltation, and suspension; the other at measuring the various dimensions of rivers and canals which flow in erodible channels, and at deriving empirical "laws" from an analysis (frequently graphical) of the collected data. Although more progress has been made in the work of the school of research workers pursuing the first aim (notably by R. A. Bagnold in this country*) since Dr. Leliavsky wrote his book in about 1953, he shrewdly remarks that it is the second, empirical, school which has so far provided the engineer with readily comprehensible and usable data and techniques. That there is no clearly defined dividing line between the two schools is admitted by the author. The research workers of the "physical" school have frequently sought to combine their rigorously derived formulae with the empirical laws derived from field observations, and the "empirical" engineers, in particular Gerald Lacey, have continually striven to cast their "laws" in forms which have general physical significance.

More space is given in Dr. Leliavsky's book—as appears proper to the present reviewer—to the work done by many of the outstanding research scientists in this field on the elucidation of the physical causes and mechanisms of the interaction between the flowing water and the erodible bed; but he also presents very well an appreciable body of more immediately useful information on empirical formulae.

In his main chapters the author deals with dunes and ripples; with the basic scour criteria: pick-up velocity, drag and lift; with the three-dimensional characteristics of the water flow and the "non-parallelism principle"; with the mechanical explanation of sediment suspension; and with the empirical approach to the sediment-transportation problem and the empirical formulae so deduced.

As mentioned earlier, many outstanding minds have devoted themselves to the problems which the author describes and discusses, and indeed are still engaged upon it. It cannot be expected that each of them would approve his treatment, nor would he himself claim any degree of finality in his process of definition, discussion and conclusion. He has, however, achieved a remarkable measure of success in bringing together, for the first time, in the compass of a relatively modest book most of the outstanding theories of interest to the specialist in this field, together with practical design ideas and formulae within the understanding of the engineer practising in related fields such as water-power engineering.

Annuaire Hydrologique de la France, 1954. Société Hydrotechnique de France, 199 Rue de Grenelle, Paris VII. 200 pp. Price 2,000 fr. net.

This annual publication gives a detailed analysis of the hydrology of all the main catchments in France, the daily records of river flows and the monthly rainfall figures being given for each catchment. The annual mean flow for each catchment is compared with the 1920-1954 average and also with the average since records for the catchment were commenced. Amongst the many charts published are included graphs showing the weekly state of the principal reservoirs throughout the country.

Two further hydrologic stations have been put into service during the year—at Montjean on the Loire and at Epinal on the Moselle—bringing the total number of stations now in service to 71.

According to an analysis of the characteristics of the year, presented by M. de Beauregard, after a drought in 1953 the year 1954 returned to a rainfall only slightly below the long-term average. In the north of France the rainfall was 88 per cent. of the average and in the south no less than 98 per cent., the figure for France as a whole being 92 per cent. of the long-term average.

I.E.C. Recommendations for Power Transformers (Publication No. 76). International Electrotechnical Commission, 39, route de Malagnou, Geneva. 71 pp., 5ff. French and English text. Price 10 Swiss francs net.

Work on this subject was commenced in 1937 and considerable progress had been made by 1939, when a final draft had been prepared. Owing to the war, this document was not published and when the war was over it was found necessary to recommence the work in order to take technical progress into account. These recommendations replace the earlier rules, formerly published in the I.E.C. Rules for Electrical Machinery.

The recommendations contain the following sections: Scope of recommendations — Definitions — Losses and efficiencies — Tolerances — Limits of temperature-rise — Temperature measurements — Insulation levels and tests — Ability of transformers to withstand a short circuit — Rating plates — Standard kVA ratings — Standard tappings — Definition and designation of connections of three-phase transformers. The following appendices are also included:

* See *Proc. Roy. Soc.* and *Proc. I.C.E.*

Designation of three-phase transformer connections and phase-angles — Connection in parallel of three-phase transformers — Calculation of voltage regulation — Classification of insulating materials — Nominal and highest system voltages.

Geology in Engineering. By John R. Schultz and Arthur B. Cleaves. John Wiley & Sons, Inc., New York; Chapman & Hall Ltd., London. 592 pp. 208 ff. Price $8·75 or 70s. net.

As was pointed out by Dr. Richey in his recent series of geological articles in WATER POWER, the geologist and the civil engineer have much in common but their viewpoints are essentially different. There are certain matters of vital importance to the pure geologist which are of little or no significance to the civil engineer, whereas the engineer is apt to require geological information of a kind in which the geologist, as such, is only faintly interested. Yet the value of accurate geological analysis to the civil engineer is obvious, and nearly as obvious is the contribution that the engineer's burrowings can make to geological knowledge. Thus, anything that helps to place the two sciences *en rapport* is bound to be of mutual benefit.

It is with such thoughts in mind that we give this book an unstinted welcome, for it has been written by professional geologists with the specific object of meeting the requirements of the civil engineer. Throughout the book the scale of values appropriate to the engineer has been admirably grasped, and the result is a volume that can be read profitably both by the engineer with scanty geological knowledge and by the geologist unfamiliar with the problems facing the civil engineer.

The book commences with a chapter on the relationship between geology and engineering, and then proceeds to describe minerals, rocks and geologic structure. The phenomena of subsurface water are then discussed followed by chapters on rock weathering and soils, erosion and deposition by streams, desert land forms, and shore lines and beaches. Glaciers and glaciation are then considered, followed by frost action in soils, landslides, volcanoes and earthquakes. The principles of historical geology are then expounded, followed by chapters on geologic maps and sections and on the aerial photographic interpretation of soils. A useful chapter on soil mechanics is contributed by E. J. Yoder, and the remaining chapters deal with subsurface exploration and with the specifically engineering applications of geology to dams and reservoirs, tunnels, highways and airfields, and concrete aggregates.

Flood Estimation and Control. By B. D. Richards, B.Sc., A.C.G.I., M.I.C.E. Third Edition. Chapman & Hall Ltd., 37 Essex Street, London, W.C.2. 187 pp. 49 ff. Price 35s. net.

Since its first appearance in 1944, this book has become firmly established as a standard work on the subject. It embodies an original analytical method of flood estimation which was first presented by the author in 1937 in the form of a paper to the Institution of Civil Engineers and for which he was awarded the Crampton Prize. In the book the author's method is fully and lucidly expounded, and in chapter X Mr. Richards submits his method to the acid test of comparing his calculated estimates for certain British catchments with actual records of important floods that have occurred there. The comparisons are fascinating and satisfying.

In this third edition an important addition to the comparisons just mentioned is the case of the disastrous Lynmouth flood of August 1952, and an estimate is made of the intensity of this flood and of maximum normal and maximum catastrophic floods from the catchment.

Other useful additions include a fuller discussion of the unit-hydrograph method, the adaptation of the author's methods to the special case of a reservoir of large area in proportion to the catchment, the development of a method of constructing the hydrograph of a flood produced by a moving storm, the application of the author's theory to large catchments with a very long period of concentration, and a fuller statement of the author's approximate method of calculating the flood absorption effect of a reservoir.

Glenfield Gazette. The December 1955 issue of the *Glenfield Gazette* contains an interesting description of the Low Tana hydro-electric development in Kenya, for which Glenfield & Kennedy Limited, Kilmarnock, supplied the dam sluice gates, the intake gates and screens, and the main turbine valves. Other articles relate to sleeve regulating valves for low and moderate-head free-discharge culverts, plough rakes for vertical bar screens, a new waterworks sluice valve, the Broken Scar works of the Tees Valley Water Board, and a beam pumping engine for the Colne Valley Water Company—the last engine of this type made by Glenfield & Kennedy Limited, and probably the last to be made in the world.

Lubrication Bulletins. The Vacuum Oil Company Limited, Caxton House, Westminster, S.W.1, have sent us the first six of a new series of industrial technical bulletins giving the characteristics and uses of various lubricants and the choice of lubricants for particular services. The titles are as follows: No. 1, S/V Ceremuls; No. 2, Industrial Petrolatums; No. 3, Gargoyle Grease BRB No. 1 and Ball and Roller Bearing Lubrication; No. 4, The Gargoyle Compounds and Enclosed Gear Lubrication; No. 5, Oils for the Machine Shop; No. 6, The Gargoyle Dorcias and Open Gear Lubrication. The associated Mobil Oil Company Limited has commenced publication of *Mobil Industrial Review*, which will appear quarterly. The first number contains a series of articles devoted to the diesel engine and its lubrication.

Electronic Computers. Ferranti Limited, Hollinwood, Lancashire, have published a most interesting brochure on the subject of electronic digital computers, which has been issued on the occasion of the installation of the Ferranti Manchester Digital Computer at the Istituto Nazionale per la Applicazioni del Calcolo in Rome. An account is given of the history and achievements of this body as well as of the Italian National Research Council under whose auspices it operates. Illustrations of the Rome installation and of others in the United Kingdom are included, and an outline is given of the calculating capacity of the machine. The value of such an installation, in accuracy and in time saving, in the performance of elaborate and tedious calculations, such as are involved, for instance, in dam design, needs no emphasis.

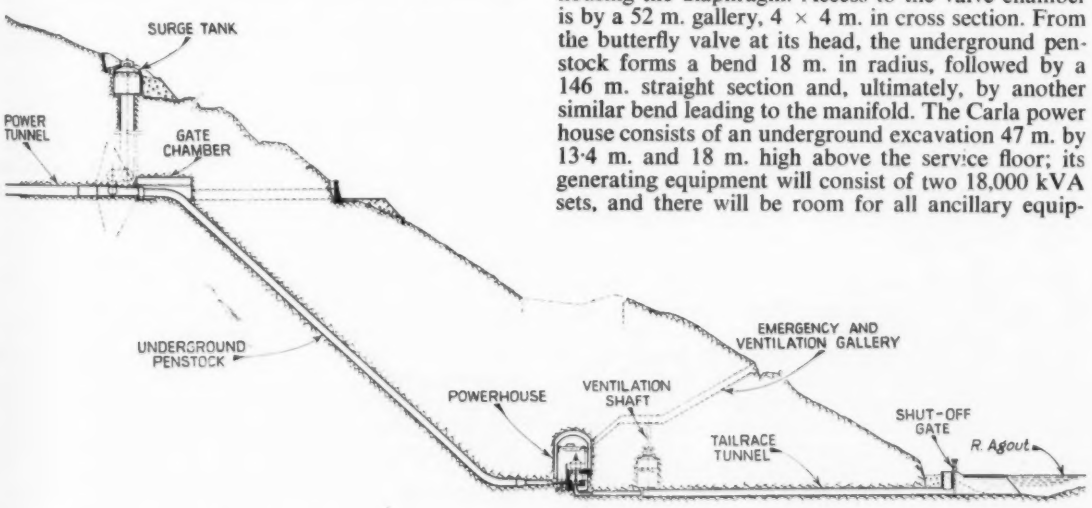
The Agout Development

An outline is given of a French development in the Département de Tarn

THE Agout river, a tributary of the Tarn, rises near the junction of three Départements of France—Tarn, Aveyron, and Hérault, in an abundantly watered region. Electricité de France has planned its development in two constructional phases of which the second—the Brassac stretch of the Agout—is still under investigation. The first phase, on which work is in progress, covers the Raviège and Luzières dams, together with the power equipment to utilise the head in the Carla section. Once completed, the development will extend from the small market town of La Salvetat to Castres.

By closing the vast basin stretching downstream from La Salvetat, the Raviège dam will create a gross storage of 45 million cu. m. which will form the first stage of the Brassac development, and also serve as a regulation reservoir for the downstream plants. Two alternatives are contemplated: a gravity dam, triangular in cross section, and a buttress structure of the hollow conoïdal type, both 33 m. in height above the river bed, with a 200 m. crest carrying a 5 m. wide roadway provided with cantilever footpaths. The gravity dam consists of 13 blocks ranging in length between 14 and 17 m., of which block III, counting from the left bank, will incorporate the intake works of the future Brassac plant, and block V the outlet equipment; blocks VI and VII will carry two 11 m. × 5 m. tainter-gates with ski-jump spillways. The intake and gate chamber will be housed in blocks V and VIII flanking the spillways and, in addition, block VIII will also carry the intake structures to the turbine. Pending the completion of the whole development, the 4,000 kW generating set provided will utilise the waters of the Raviège reservoir. The substructure of this generating set, together with its tailrace, alternator platform and H.T. switchgear, will be sited at the foot of the dam on the right bank. The alternative project of a buttress dam provides for 12 T-shaped buttress blocks, the arrangement of the equipment and the equipment itself being the same as for the gravity dam. The volume of concrete involved in the two alternatives is 57,700 and 44,500 cu. m. respectively. The impermeability of the dam will be ensured by a cut-off trench and a network of grout holes; immediately downstream of the cut-off trench, control drains, to be bored later on, will lead from the inspection gallery into the foundation rock. The drainage of the dam is to be effected by 0·5 diameter vertical holes opening on to the inspection gallery.

The Carla development, with a gross head of 140 m. and a discharge of 26 cu. m. per sec., lies between the villages of Vabre and Burlats. At Vabres, the Gijou river, which otherwise flows into the Agout at Bouissas, downstream of the Luzières dam, will be diverted into the Luzières reservoir by means of a 1,250 m. tunnel and a steel conduit, 45 m. in length, designed for a maximum discharge of 10 cu. m. per sec. The Luzières dam, 20 to 23 m. in height above the Agout bed and 123·5 m. in length at the crest, is situated at a point where an outcrop crosses the river, so that its foundations will rest throughout on granite; it consists of a 24 m. long middle section, forming block No. IV, and of two wing sections comprising three 12 to 14 m. blocks on the left bank and five on the right bank. The middle section carries two ski-jump spillways, and houses the emptying sluices, the whole block being designed for a flood discharge of 1,000 cu. m. per sec. The power tunnel stretches over 7,330 m. between its intake immediately upstream of the Luzières on the left bank and the axis of the surge tank, and is designed for a discharge of about 85 cu. m. per sec. The surge chamber, 5·5 m. in diameter by 31·5 m. in height, is topped by an expansion chamber 10·6 m. in diameter. To make construction work easier, it is placed off the axis of the tunnel to which it connects by a gallery about 10 m. long housing the diaphragm. Access to the valve chamber is by a 52 m. gallery, 4 × 4 m. in cross section. From the butterfly valve at its head, the underground penstock forms a bend 18 m. in radius, followed by a 146 m. straight section and, ultimately, by another similar bend leading to the manifold. The Carla power house consists of an underground excavation 47 m. by 13·4 m. and 18 m. high above the service floor; its generating equipment will consist of two 18,000 kVA sets, and there will be room for all ancillary equip-



ment, a busbar floor, drainage galleries, control room, etc.

An efficient air-conditioning system will be provided. The main access gallery to the power plant will also house the transformer cubicles, the cooling plant, and the oil servicing and storage equipment. The transformer untanking room, equipped with a 55 ton stationary hoist and a 6 ton travelling crane, will be sited on the edge of the roadway, close to the entrance to the access gallery. The downstream surge chamber, 8 m. in diameter by 12 m. high, stands above the point where the turbine draught-tubes connect with the tailrace, from which it is separated by a thick reinforced-concrete floor in which are provided grooves for the downstream stoplogs and isolating sluice. The top floor forms the stoplog service room which connects direct with the emergency and the ventilation gallery by a 2 m. diameter shaft. The 116 m. tailrace is to operate under slight pressure, and will have a 1·66 per cent. gradient throughout. The emergency and ventilation gallery, 10 sq. m. in cross-section and 90 m. in length, opens on to a secondary road at an elevation of 237·5 m., and is connected with the inclined aeration gallery leading from the ventilation room, with the emergency gallery of the machine hall, and, through the air intake, with the downstream stoplog service room.

The Carla outdoor installations will extend over a length of about 200 m. between a secondary road and the Agout river. The switchyard, ancillary buildings and workshop will be sited at elevation 201·5 m. on a platform which terminates at its downstream end to make room for the tailrace. (Gabriel Héke, *L'Equipement Mécanique*, Nos. 302-3.)

Symposium on Arch Dams

The Power Division of the American Society of Civil Engineers has arranged a Symposium on Arch Dams to be held as part of the summer meeting of the Society at the University of Tennessee in Knoxville, Tennessee, June 4-8, 1956. The programme of papers to be presented is given below:—

Session 1. Tuesday Morning, June 5

(a) 1. "The Kamishiiba Arch Dam, Japan." C. C. Bonin, Chief Civil Engineer, Ebasco Services Incorporated; H. W. Stuber, Civil Engineer, Ebasco Services Incorporated; K. M. Mathisen, Ebasco Services Incorported.

(a) 2. "Results of Measurements on Kamishiiba Dam." H. Kamishima, Civil Engineer, Kyushu Electric Company, Japan.

(b) "Portuguese Experience with Overflow Arch Dams." A. C. Zerez, Chief Engineer, Hidro Electrica do Zezere, Portugal.

Session 2. Tuesday Afternoon, June 5

(a) "Design and Construction of Ross Dam." C. E. Shevling, Department of Lighting, City of Seattle; L. R. Scrivner, Concrete Dams Section, U.S. Bureau of Reclamation.

(b) "Stress Measurements at Ross and Diablo Dams." C. E. Shevling, Department of Lighting, City of Seattle; Joe T. Richardson, Concrete Dams Section, U.S. Bureau of Reclamation; Owen J. Olsen, Engineering Laboratories, U.S. Bureau of Reclamation.

Session 3. Thursday Morning, June 7

(a) "The Philosophy of Arch Dams." A. Coyne, Consulting Engineer, Paris, France.

(b) "The Development of Arch Dams in Italy." C. Semenza, Manager of Hydraulic Construction, Societa Adriatica di Elettricita, Venice, Italy.

(c) "Methods of Calculation and Model Confirmations." G. Oberti, Director Institute Sperimentalè Modelli e Strutture, Bergamo, Italy; D. Tonini, Director of Studies, Societa di Elettricita Venezia, Venice, Italy.

Session 4. Thursday Afternoon, June 7

(a) "Design and Observation of Arch Dams in Portugal."

(1) "Improvements in Designs through Model Tests." J. Laginha Serafim, Laboratorio National de Engenharia Civil, Lisbon, Portugal.

(2) "Observed Structural Behaviour." A. F. da Silveira, Laboratorio National de Engenharia Civil, Lisbon, Portugal.

(3) "New Trends in Experimental Studies of Dams." M. Rocha, Laboratorio National de Engenharia Civil, Lisbon, Portugal.

(b) "Trial Load Studies for Hungry Horse Dam." R. E. Glover, Engineer, Denver; Merlin D. Copen, Concrete Dams Section, U.S. Bureau of Reclamation.

Review of Experience—A Compilation

Session 5. Friday Morning, June 8

(a) "Theory, Methods and Details of Grouting Contraction Joints in Arch Dams." A. W. Simonds, Concrete Dams Section, U.S. Bureau of Reclamation.

(b) "Economics of Dams." L. G. Puls, Head of Concrete Dams Section, U.S. Bureau of Reclamation.

(c) Review of Experience—A Compilation.

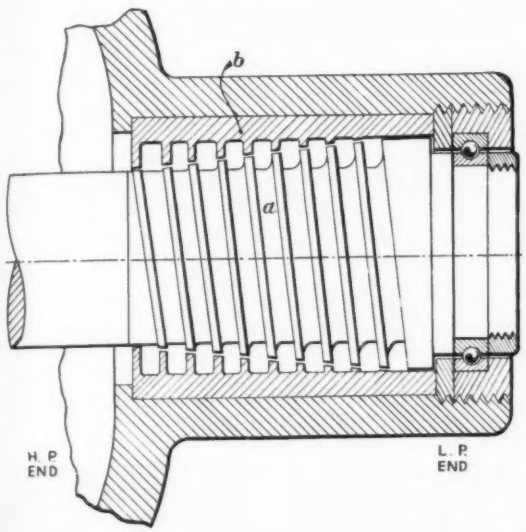
A review of experience with arch dams will be made a feature of the meetings. Experience records, illustrated with colour slides in most cases, have been received from France, Norway, United States, Mexico and New Zealand and more are expected.

Communications relating to offers of discussions should be addressed to Mr. R. E. Glover, Chairman, Arch Dam Symposium Committee, 1936 South Lincoln Street, Denver, Colorado, and communications relating to sale of papers should be addressed to Mr. Harold T. Larsen, American Society of Civil Engineers, 33 West 39th Street, New York 18, New York.

Remote Metering Systems. George Kent Limited, Luton, have forwarded a pamphlet describing electrical systems for transmitting measurements of flow, level and similar functions over a distance. A circuit for short-distance transmission and two alternative circuits for long-distance transmission are given. These circuits are used in conjunction with the firm's standard mechanical meters, presenting the advantage that the mechanical and electrical systems can be tested and adjusted separately, and the receiving instruments can be of the indicating, recording, integrating, or Multelec type.

New Principle in Design of Sealing Glands

A design of turbine and pump sealing gland which is based on a revolutionary principle has been devised and patented by Dr. M. S. Frenkel, a consulting physicist and engineer. The design is shown diagrammatically herewith, and at first sight may appear similar to an ordinary screw gland, but it contains features that make its method of functioning widely different from that of a normal screw gland, and it is claimed, much more eeffctive. It is claimed, in fact, that with a gland properly proportioned for the pressure difference involved, the leakage will be nil. Indeed, the gland may actually draw in air against the water pressure—an eventuality that can be circumvented, if necessary, by incorporating a reverse stage at the low-pressure end.



Reverting to the illustration, the rotating shaft carries a screw thread *a* the lands of which lie on the frustum of a cone rising from shaft diameter at the high-pressure end to a maximum at the low-pressure end; in consequence, the groove cross section increases from zero to a maximum in passing from the high-pressure to the low-pressure end. This screw is handed in a direction to pump the water back towards the high-pressure end.

Enclosing this screw is a stationary sleeve *b* in which is cut a screw thread the lands of which follow an identical conical frustum to that followed by the thread on the shaft, but as the sleeve thread is an internal one the groove cross section decreases progressively from a maximum at the high-pressure end to zero at the low-pressure end.

The action of the gland can best be considered by contrasting it for a moment with that of a normal screw gland. In the latter case the screw is cylindrical and operates within a plain cylindrical sleeve. There is therefore a straight leakage path along the internal surface of the sleeve, this leakage being impeded by the pumping action of the screw and by the pressure loss due to the flow past the lands of the thread. Leakage in this case cannot be nil because this pressure loss depends on the existence of a flow.

In the Frenkel gland, for reasons to be given in a moment, the water does not follow a straight leakage path across the thread lands, but flows helically through the grooves of the internal thread in the sleeve. This action alone increases the length of the leakage path in the ratio $2\pi rn : 1$ where r is the mean radius of the screw and n is the number of threads. In following this path, however, the water has to accommodate itself to a progressively diminishing cross section of groove, with the result that there is a radial transfer of water to the grooves of the rotating screw on the shaft. In this screw the water is pumped back towards the high-pressure end, but once again has to accommodate itself to a progressively diminishing cross section of groove, so that a radially outward transfer to the grooves in the sleeve takes place. Thus, throughout the gland there is a continuous radial flow in one direction or the other, and it is stated that this motion completely inhibits any tendency to leak across the lands of the threads towards the low-pressure end.

A further inhibiting action is provided by vortex motion within the threads. It can be shown, in fact, that in any pair of facing grooves in sleeve and shaft respectively, two vortices, one in each groove, are set up in opposition to each other.

The functioning of the gland has been described in terms of the flow system set up, but it can also be considered in terms of fluid friction, for the increased length of leakage path along the sleeve helix, the constant change in direction of motion due to the radial transfer, and the vortex action in the grooves, combine to produce a condition of fluid friction many times more intense than that obtaining in a normal screw gland.

From a practical standpoint, too, the design has much to recommend it. As its action does not depend in any way on flow across the lands of the threads, the clearance between the threads is not critical, and in consequence, assuming clean water, the gland operates without mechanical friction and without wear. In any event, if it is thought desirable to introduce an adjustment for clearance, this can be effected very simply by providing an axial adjustment of the sleeve. Assembly is also made a simple matter by the normal expedient of using a split sleeve.

Dr. Frenkel obtained his doctorate at Vienna University but migrated to England before the war, during which he was in charge of research for Coventry Climax Engines Ltd. He is now practising as a research and consulting physicist, mathematician and engineer, and has achieved a reputation for the solution of fundamental engineering problems, purely theoretically and without laboratory research, these solutions having been subsequently experimentally confirmed on his own designs. His interests have included quantum physics, oscillatory phenomena in ball and taper-roller bearings, exhaust-gas ejectors, variable-speed control mechanisms, equipment for the plastics industry for which he designed a mixer and extruder based on the same principles as the gland we have described, and mineral crushers of similar basic design.

Super-Tension Cable Manufacture

One of the outstanding hydro-electric developments of the present day is the Kemano-Kitimat plant, and anything connected with it is likely to make history. This remark applies in full measure to the super-tension cables connecting the underground transformers to the overhead transmission line, as they are constructed to operate at 301 kV. Pirelli-General Cable Works Limited, an associated company of The General Electric Co. Ltd., England, and Pirelli S.p.A., Milan, are just completing a repeat order for this 301 kV cable for Kitimat, and will have supplied about two miles of it. The cable is of the single-core oil-filled type, and its construction is shown in Fig. 1. It is designed for a maximum working stress of 120 kV per cm.

We were recently privileged to visit the company's Eastleigh works to see the cable in course of manufacture and to study the exceptional methods employed to ensure, as far as is humanly possible, 100 per cent. consistency of result.

With super-tension cables the outstanding manufacturing problem is to secure the most exact control of the paper-wrapping process, as the slightest inconsistency may result in the formation of kinks or wrinkles which, although slight in themselves, would be sufficient to act as points of potential breakdown. Thus, in the first place, the distance between the edges of successive turns of a layer and also the extent of overlap between successive layers must be capable of precise adjustment so that the cable can be coiled on its drum and subsequently removed without disturbance to the wrapping, and furthermore, the tension to which the paper tapes are subjected during wrapping must be uniform. But even this is not sufficient, because paper is hygroscopic and expands and contracts according to its moisture content. Thus any variations in the moisture content of the various tapes would result in unequal tensions in the layers of the completed wrapping, with potentially disastrous results.

These problems have been overcome by the use of a wrapping machine, depicted in Fig. 2, which was designed and built by the Pirelli Company in Milan and is claimed to be the only machine of its kind in Great Britain. This machine is housed in a fully air-conditioned chamber, together with a paper-cutting machine, and all paper stock, after being cut, is held in this chamber for at least four days before use.

The wrapping machine consists of 20 reversible lapping heads, one of which is seen in Fig. 3, each capable of applying 10 papers, so that up to 200 layers of insulation can be applied simultaneously. It is thus possible to insulate cables for 300 kV and above in one operation. The most important feature of the paper-lapping machine is the paper-tensioning device. Tension is imparted to the paper by means of a spring-controlled band brake acting on the pad holder. The paper passes to the cable over four rollers, one of which is attached to a pivoted lever, which is itself spring controlled and coupled by linkwork to the

Fig. 1. The Kitimat 301 kV cable

Fig. 2. The wrapping machine for super-tension cable

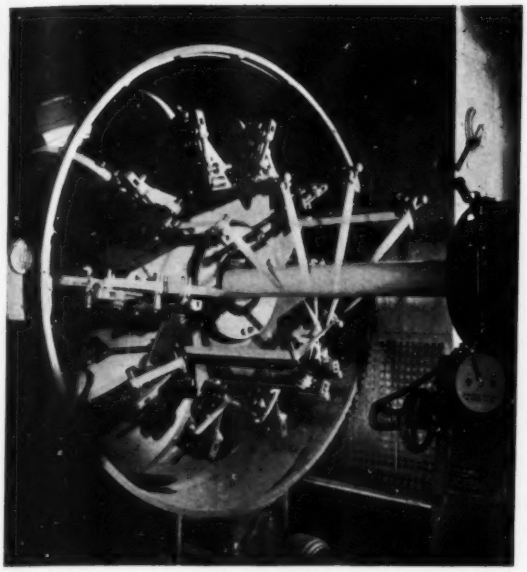


Fig. 3. One of the wrapping heads

band brake. The paper tension is predetermined by selecting springs (which are interchangeable) of the requisite strength. Valuable properties of the paper-tensioning mechanism are that it is unaffected by centrifugal forces and that it maintains correct tension even when the machine is stopped and despite the slight, unavoidable backlash. Accurate registration of the paper tapes is controlled by means of a fine graduated screw adjustment to the position of the last roller over which each paper passes. There is also an adjustment for the angle of the paper holders to ensure that the centre plane of the paper pad is tangential to the cable. The adjustment moves all 10 holders of a head together.

Each of the 20 lapping heads is driven through a positive infinitely variable-speed gear, the direction of rotation being changed when required simply by the movement of a small lever. The machine can be stopped or started by pushbutton controls situated on each head. Simultaneous braking of all heads is provided by an electro-hydraulic mechanism operating through a layshaft. For safety in operation, all the lapping heads are partially enclosed by a transparent guard; a knock-off device on each head stops the machine if a paper breaks or runs out or if a guard is lifted, and also lights a red lamp on the head affected. Cable is drawn through the machine by means of a caterpillar-type haul-off.

An air duct runs the full length of the paper-lapping enclosure, and conditioned air is blown from a number of outlet louvres across the top of the enclosure. After circulating, the air is extracted through apertures at floor level by a fan in the return air ducting, and is returned to the conditioning plant with a proportion of fresh outside air which is continuously added. Once the required temperature and humidity values have been set the whole plant is automatically controlled to maintain even conditions through summer and winter. Over a measured test period, the outside temperatures varied between 34° and 63°F., with relative humidities of 48 per cent. to 84 per cent. Throughout this period conditions in the enclosure remained constant without attention at the preset values of 70° F. and 40 per cent. relative humidity.

Additional test facilities have been installed to carry out development and type approval tests on these very high-voltage cables, and the Kitimat cables have been tested at the 1,050 kV level. In the development bay, a Micafil impulse generator has been installed having a stored energy of 38,500 watt seconds and an open-circuit voltage of 1,600 kV peak. The generator is capable of applying impulses up to 1,400 kV peak on samples of cables, including accessories, up to about 25 yards in length. Also in the development bay are two 330 kV Ferranti transformers which can be operated either in parallel or in cascade to give a total voltage of 660 kV to earth. Impulse and a.c. voltages are measured by a sphere gap between two 1 m. diameter copper spheres.

For routine testing of the long lengths of high-voltage cable which are now demanded, a further pair of transformers each having a maximum voltage of 200 kV has been installed in a second enclosure. These have a combined rating of 1,600 kVA continuously, or 2,800 kVA for half an hour; the transformers can be operated either in parallel, at 200 kV, or in cascade, at 400 kV. Both transformers are provided with built-in variable reactors connected across the primary windings. The reactors are remotely controlled so that they can be adjusted to compensate for the capacity current of the load; this results in the transformers being considerably smaller than would otherwise have been possible.

These special manufacturing and test facilities should place Pirelli-General in a very secure position in undertaking orders for the very high-voltage cables liable to be called for in important new hydro-electric schemes.

Mullardoch Induction Generator

In the course of our description of the Glen Affric scheme, Scotland, in our May, June and July 1952 issues we recorded that preparations were being made for the eventual installation of a subsidiary underground power station at Mullardoch to take advantage of a difference of level of about 80 ft. between Loch Mullardoch, which constitutes the main storage for the scheme, and Loch Benevean, which forms the headpond for the main station at Fasnakyle.

The generating set in this subsidiary station is now in service. It is a Bruce Peebles 2,400 kW induction generator coupled through a David Brown 208/755 r.p.m. right-angled speed-increasing gear to a Gilbert Gilkes & Gordon vertical Francis turbine.

This induction generator is believed to be the largest of its type to be installed in Great Britain, but sets commissioned in Norway, New Zealand, British Guiana, Malaya, Kenya, Tanganyika, South Africa, and British West Indies, include units up to 4,000 kVA.

Bruce Peebles & Co. Ltd. are now completing the second of two 13,333 kVA vertical waterwheel alternators for the North of Scotland Hydro-Electric Board's station at Glascarnoch, and have received orders for a 20,000 kVA generator for the Orrin scheme and a 11,111 kVA machine for Dolgarrog power station, North Wales.

New Atlas Copco Portable Compressor

The Atlas Copco 250 Monobloc portable compressor

Atlas Copco have introduced a new model to their range of portable compressors. The 250 Monobloc which gives a free air delivery of 250 cu. ft. per min. is based on actual operating experience gained with their HR4V compressor in many different parts of the world. This machine is built on the monobloc principle, with a two-stroke diesel engine having no valves, and a double-acting compressor of the cross-head type. With the monobloc system, developed by Atlas, engine and compressor are designed for each other, and they are integral and not separate units as in conventional designs. The Monobloc unit has: One crankshaft, one air intake, one cooling system, one circulating-water pump combined with one fan for the engine radiator and the compressor intercooler, one lubrication system with one oil pump, no engine valves, valve gear or camshaft, no clutch and no electrical system, and only one gear for force-feed lubricating pump.

A new type of oil-level gauge for the fuel oil tank has been introduced, incorporating a plastic float fitted with an indicator rod, the position of which can be seen in a plastic tube located under the tank. The plastic tube is fitted with a drain cock which makes it easy to drain off any water and sediment deposited in the bottom of the tank. The circulating-water pump is effectively sealed against leakage. This should be of value in countries where anti-freeze mixture is used, as the volume of liquid lost is negligible. The regulating valve for the automatic unloading of the compressor has been so designed that it can be drained of any oil or water so as to eliminate breakdowns from freezing during the winter months.

An automatic exhaust throttle is also a new feature. The throttle is balanced in such a way that the exhaust stream can open it and keep it open during operation. A gravity return to the closed position results when the unit stops. This automatic exhaust throttle eliminates two working movements which must otherwise be remembered, i.e., to open the throttle when starting and to close it after having stopped the unit.

As large diesel engines are difficult to start by hand and electrical devices with accumulators do not stand up to hard working conditions, Atlas Copco have introduced the powder-cartridge starting method. By simple manipulation a powder charge is exploded in the engine cylinder nearest the flywheel; the engine piston is depressed and the crankshaft starts rotating. When the pistons in the other cylinders reach their top dead centres, ignition-paper rolls in the cylinders are ignited by the heat developed during compression.

The fuel oil tank has been made for 30 Imp. gal. which is sufficient for 10-12 hours' operation, eliminating the need to refuel during a working shift. Facilities for fuelling have been improved as the tank has been fitted with a large filling cover with strainer so that now refuelling can be carried out direct from the tanking vehicle.

An Atlas-designed oil-bath air-intake filter is located at the rear of the machine, which means that the coldest possible air is used. This factor has a marked effect on the output of the compressor.

The front part of the chassis has been so designed that the wheels can be adjusted easily for accurate steering in the same way as on a motor car, so that the 250 Monobloc runs safely on tow even at high speeds. The dimensions of the towing and steering devices have been designed to allow for the severe stresses involved when moving over rough ground. The draw-

bar is hinged, with the result that the unit takes up less space when loaded on a railway wagon or a truck. It can be raised out of the way when the unit is installed on site. The two rear wheels are fitted with brake drums actuated by a brake lever on the right side of the machine. By fastening a rope or cable to the lever the brake can be operated while the unit is on tow. Track width is 58 in. and wheel base 77 in.

Folding side shutters enable the unit to be uncovered quickly.

British Bulldozer on Finnish Scheme

The Fowler Challenger 3 machine at work on site in Finland

A new power station for one of Finland's largest smelting works is now nearing completion only a few miles from the Russian border. River-diversion channels have been cleared by a 95 b.h.p. Fowler Challenger 3 diesel crawler tractor equipped with a Bray hydraulic bulldozer. The power station is at Huhtilampi and is intended to serve the smelting works at Wartsila in East Finland. Before the last war a large power station supplied all the power necessary for the works, but it is now in Russian hands. After the war a smaller power station was built, which, however, did not have sufficient output, and the new scheme is intended to remedy the deficiency. The new station's entire output will be used to meet the demands of the smelting works.

The main problems facing the engineers were the cutting of river-diversion channels from solid rock, and finding a machine to clear loose rock which could stand up to the strain of the conditions imposed by the site. The latter problem was solved by the Challenger 3 tractor which was used to bulldoze the loose rock to the excavators which loaded it into dump trucks. Although the main body of water was held in check by temporary dams made of pine logs, the tractor was usually working in almost two feet of water. Over the whole construction period, approximately 70 per cent. of the material moved was rock.

The versatility of the Challenger 3 has been put to good use by the construction teams. Before the diversion plan was put into operation the Challenger 3 was used to cut out new roads through the rocky ground of the pine forests. During the worst of the winter months the tractor was used to free existing roads from snow, and it has also been used to strip overburden from gravel pits.

The Challenger 3 diesel crawler tractor is manufactured by John Fowler & Co. (Leeds) Ltd., England, and the machine is shown in action above.

Abstracts from the World Technical Press

The New Lienne Project

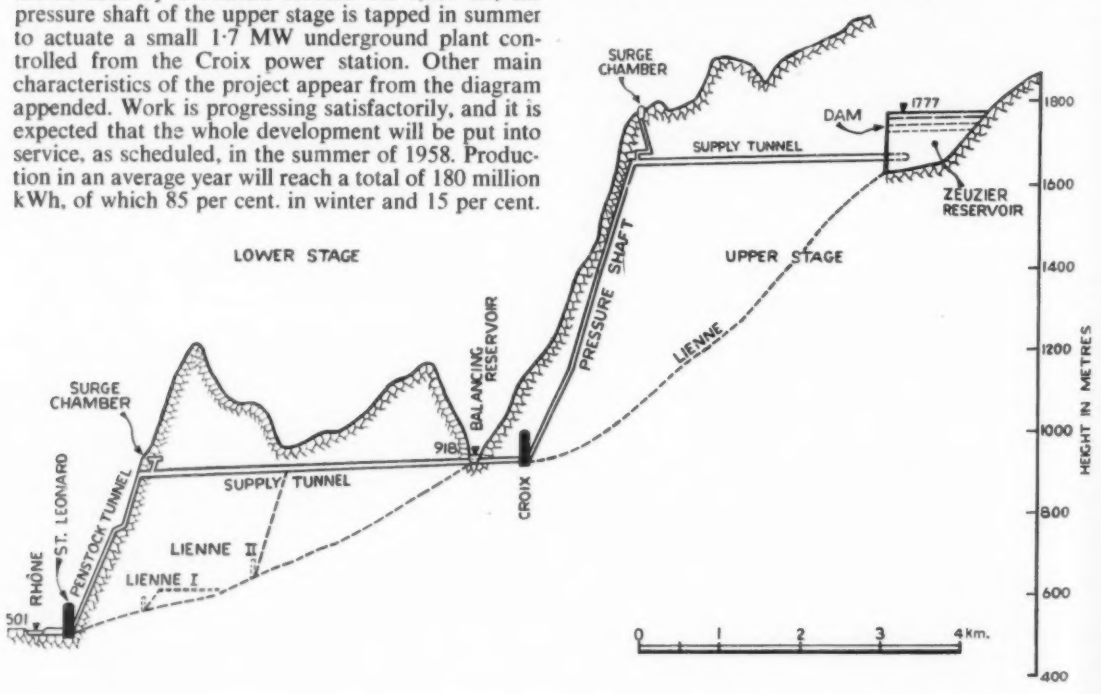
Up to now the Lienne River has been harnessed to hydro-electric generation only in its lower reaches in two run-of-river plants, Lienne I and II, built by the Sion Corporation in 1907 and 1917. The new project described in this article, in course of construction since May, 1953, was worked out to develop the upper course of the river in two stages with an aggregate gross head of 1,276 m. The upper stage, which drains an area of 36·75 sq. km., operates a maximum gross head of 854 m. between the maximum level of the 50 million cu. m. Zeuzier reservoir and the tailrace of the Croix underground power station. It is designed for a discharge of 7·5 cu. m. per sec. and a capacity of 54 MW. The lower stage has a catchment of 57·55 sq. km. and utilises a maximum gross head of 417 m. between the Croix balancing reservoir and the Rhone at a rated discharge of 8·5 cu. m. per sec.; the capacity available at the St. Leonard power station will reach 28·6 MW. The Zeuzier storage is created by an arch dam 156 m. high, varying in thickness between 7 m. at the top and 26 m. at the bottom. The crest, 256 m. long, will carry a roadway connecting the two banks, and the whole structure will involve the placing of 330 million cu. m. of concrete. The Croix excavation measures 46 × 18 m. in area and 17 m. in height. The generating equipment will consist, at Croix, of two horizontal sets, each with a three-phase 27 MW alternator driven by a two-nozzle Pelton wheel, and, at St. Leonard, of two vertical 14·3 MW alternators driven each by a Francis turbine. At 1,389 m., the pressure shaft of the upper stage is tapped in summer to actuate a small 1·7 MW underground plant controlled from the Croix power station. Other main characteristics of the project appear from the diagram appended. Work is progressing satisfactorily, and it is expected that the whole development will be put into service, as scheduled, in the summer of 1958. Production in an average year will reach a total of 180 million kWh, of which 85 per cent. in winter and 15 per cent. in summer. (M. Philippin, *Wasser- und Energiewirtschaft*, Vol. 47, Nos. 5-7, May-June-July, 1955, p. 165, 5 pp., 6 ff.)

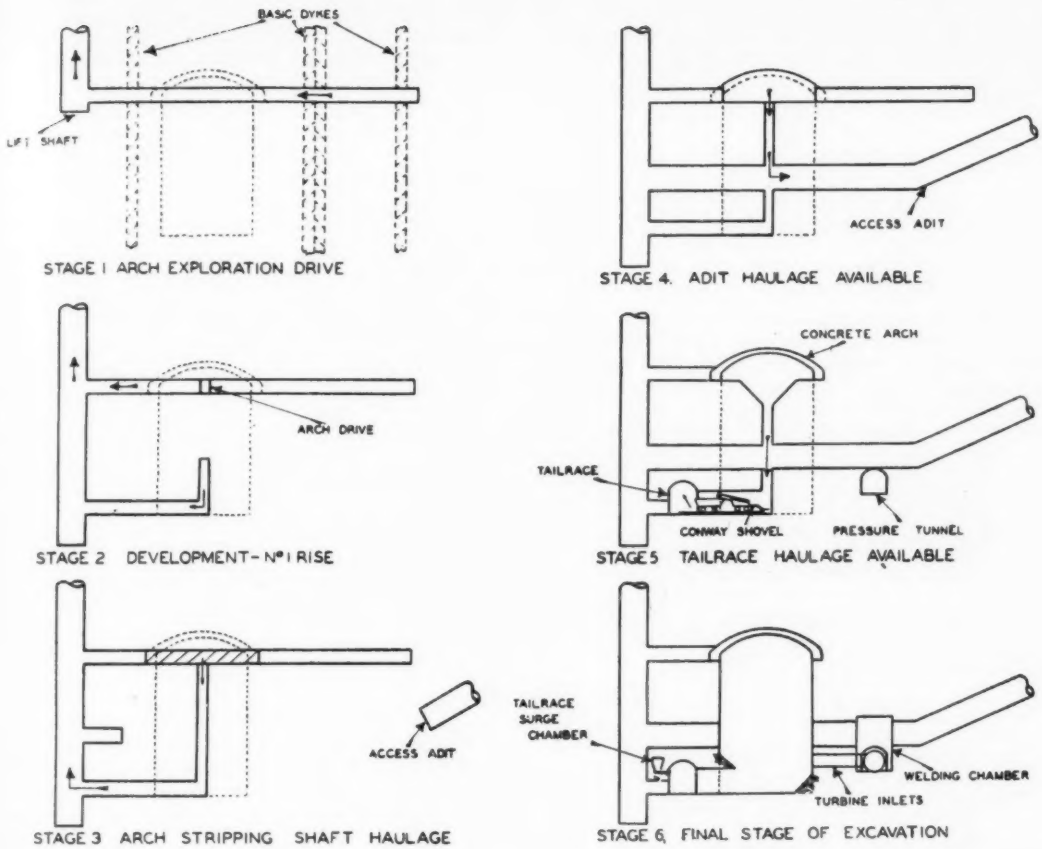
Excavation of Kiewa No. 4 Power Station

The first 15·5 MW set to be installed in the No. 4 Kiewa station, Victoria, Australia, commenced operation in February, 1955, and the station will ultimately house four similar sets. The machine hall is 130 ft. long, 42 ft. wide, and 70 ft. high inside the concrete, the total excavation being 14,000 cu. yards. The site of the station was finally determined by the orientation of a family of basic monchiquite dykes which occupy a system of nearly vertical joints traversing the country rock, which is a paragneiss derived from Ordovician sediments. The rock is normally hard and stands well when massive, but as the jointing increases in intensity, or in the vicinity of faults, the rock becomes very blocky and it is impossible to control overbreak. In addition to the longitudinal vertical joints, a series of transverse faulted joints occurred in the area, but perhaps the worst feature was a flat fault associated with a crushed zone, greasy heads and pug-filled cracks.

Access was obtained initially by a concrete-lined circular shaft 12 ft. 2 in. in diameter and about 480 ft. deep, a drive being pushed out to the preliminary site at arch level (see stage 1 in the accompanying illustration). The geological information obtained enabled the location of the machine hall to be finally determined, and a small tunnel was driven along the entire centre-line of the arch. Meantime the shaft was completed, a second drive taken at machine-hall floor level and stoping commenced to meet the arch tunnel (stage 2).

It had been planned to use the tailrace tunnel as the main access, but it was delayed by bad rock, so an inclined access adit was driven to enter the hall in the vicinity of generator floor level (stages 3 and 4). This





facilitated the stripping and concreting of the arched roof, and in the meantime the tailrace tunnel was joined up, and was used to remove the spoil from the hall excavation (stage 5). Opening up of the draft tube disclosed very poor ground conditions, mainly due to a basic dyke, and the draft tubes had to be concreted before excavation of the machine hall could proceed further. The main excavation proceeded by benching into the two rises which formed glory holes. Atlas RH656 drills, Coromant steels, millisecond detonators, and Conway loaders were employed. When the excavation was 95 per cent. complete, wall conditions deteriorated and excavation was suspended while the side walls were lined with reinforced concrete. The turbine inlet tunnels were driven through the concreted wall, and a 2,000 cu. yard welding chamber was excavated to enable the inlet pipes to be fabricated (stage 6). (R. Ian Rankin, *Chemical Engineering and Mining Review*, Vol. 47, No. 12, September 10, 1955, p. 489, 5 pp., 5 ff.)

Determining the Cross Section of a Power Tunnel

This paper, reproduced from the UNO report on the possibilities of Yugoslav exports of electric energy, refers to the preliminary project of the Split hydro-electric plant worked out in two alternatives, the power tunnel to be 10 km. in length in one, and 14·5 km. in the other, and to be driven in poor ground, thus requiring a substantial lining which will considerably increase construction costs. As the plant is scheduled to operate during certain night hours only, expenditure can be brought down by reducing the cross-section of the tunnel and turning to the best account the large reserve of water stored in an artificial lake set upstream of the penstocks. After defining the problem, the author presents its theoretical solution, followed by a numerical application and generalisation of the equations. (Maryan Leskovar, *Revue Générale de l'Hydraulique*, Vol. XVIII, No. 72, p. 316, 4 pp., 3 ff.)

Completing the Harnessing of Niagara

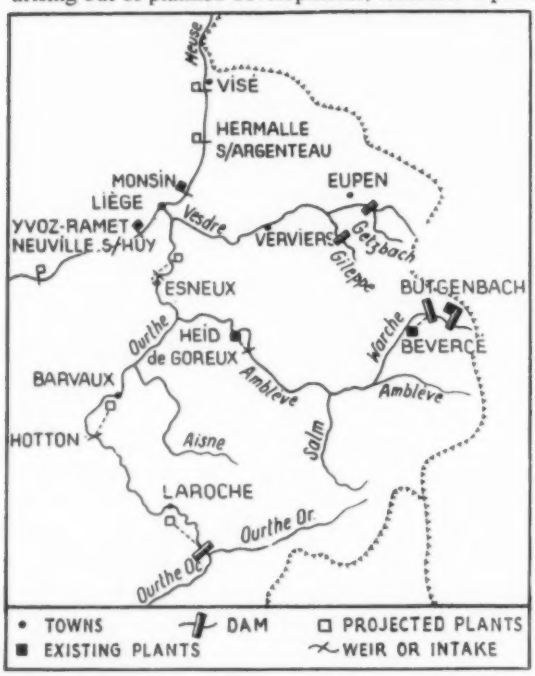
The author traces the amazing growth in demand for power in Ontario since the Hydro-Electric Power Commission of Ontario was created in 1906, and tells how the Commission's engineers have kept pace with the demand. Outlining the terms of the Niagara Diversion Treaty of 1950, he shows how this treaty made possible the undertaking of the Commission's latest and greatest development, the Sir Adam Beck-Niagara Generating Station No. 2. Ten generating units are now in operation at the main plant, and the remaining two will have been brought in by the end of the year. The 170,000 kW pumped-storage scheme, scheduled for initial operation in 1957 with completion in 1957, incorporates a storage reservoir of about 750 acres, and a pump-turbine plant which, at periods of low demand, will lift into the reservoir water from the main canal just before it reaches the forebay of the new plant; the flow will be reversed at times of high

demand and drive the six motor-generators. The addition of four units to the main plant has been authorised, and will be effected when required, to raise the total ultimate installed capacity of the station to 1,370,000 kW. (Dr. Richard L. Hearn, M.E.I.C., Chairman of the Hydro-Electric Power Commission of Ontario, *The Engineering Journal*, Vol. 38, No. 8, Aug., 1955, 3 pp., 1 f.)

NOTE. The above issue also reviews the news and progress of the St. Lawrence Seaway and Power Project, p. 108, 4 pp., 3 ff.)

Water Power in Belgium

Because of the difficulty of reconciling the various interests at stake, dams and barrages in Belgium constitute a highly controversial subject. This article lists the arguments that characterise the various problems arising out of planned developments, technical aspects



only being taken into consideration. It appears from this generalised survey that there is scant justification for purely hydro-electric schemes. It is pointed out, however, that the present state of water resources, either for town supply or industrial purposes, may induce the setting up of new dams which would also contribute to power production under favourable conditions. Two such dams are contemplated in the Meuse river regulation project—the most likely to be carried into effect in not too distant a future—one at Neuville-sous-Huy, with a useful head of 3·75 m. and an average production assessed at 34 million kWh, and the other at Lixhe, where the power station, operating under a head of 8 m., would exceed the production of 68 million kWh of the existing Monsin plant. The Ourthe river regulation project is considered less advantageous from the aspect of hydro-electric development, and is primarily intended for water supply, but the 77 m. high dam, to be erected immediately downstream of the confluence of the two upper branches of the river, would create a storage of 250 million cu. m., and with two more dams at Hotton-Barvaux and Esneux and power stations operating under heads of 40 m. and 8 m. respectively, it is estimated that the Ourthe could contribute another 105 to 115 million kWh to Belgian energy production. (Albert Schlag, *Revue Générale de l'Hydraulique*, Vol. XVIII, No. 72, July, 1955, p. 283, 6 pp., 2 maps.)

Campbell River Dam

British Columbia Power Commission recently awarded the contract for construction of the rockfill dam comprised in the first phase of the project which will merge Upper Campbell and Buttle Lakes into a 30 miles long reservoir. The dam, to be located two miles below the outlet of Upper Campbell Lake, will have a length of 1,800 ft., a width of 86 ft. at top and 1,000 ft. at base, and an earth and rock cubage of 2 million cu. yards. By raising the lake level 79 ft., 800,000 acre ft. of water will be impounded. Firm-power generating capacity will be 126,000 kW at the downstream John Hart and Ladore Falls plants, and provide 63,000 kW at the Upper Campbell Lake site. The planned second phase will raise the dam by another 30 ft. and include the installation of a 52,500 kW generating unit. This will back water into Buttle Lake 15 ft. over its normal level and form the reservoir. (*Engineering News-Record*, Vol. 155, No. 10, Sept. 8, 1955, p. 31.)

A Greek Development

The Ladhon River, which belongs to the Alphios hydrographic basin in Central Peloponnese, drains an area of 749 sq. km., timbered to the extent of no more than 15 per cent. and lying at an average elevation of 871 m. above sea level. The main works of the development, on which work started in the second half of 1952, are a light Marcello-type gravity dam, 50 m. high, which closes the valley upstream of the Pidima bridge, creating a seasonal storage of 50 million cu. m.; a diversion tunnel 8,650 m. long, 3·9 m. diameter, designed for a discharge of 34 cu. m. per sec.; a vertical surge tank 75 m. high, 6 m. diameter, with a top expansion chamber; a surface penstock 421·5 m. long, 3·3/2·85 diameter; an outdoor power station operating from a maximum head of 240 m., with two vertical 35,000 kW alternators running at 428 r.p.m., driven by Francis turbines, and an outdoor transformer station with two 32,500 kVA 15/150 kV units. A short tailrace returns the turbine discharge to the river. Owing to the topography of the site, the switchyard, from which lines lead to the towns of Patras, Kalamata, Argos, Corinth and Athens, stands apart from the transformer station, 300 m. downstream. The Ladhon plant was inaugurated on May 22, 1955, seven months after the Agra hydro-electric scheme of Agra, Macedonia. These two plants, comprised in Greece's Electrification Plan, double the capacity of the existing electricity works of the country. Their location, away from the Athens region, where most of the Greek industries are concentrated, will not only benefit rural electrification but also greatly promote the advance of industry in districts previously deprived of energy supply. Both projects were worked out and carried into effect by Società Edison, Milan, and all the mechanical and electrical equipment is of Italian manufacture. (D'AR., *Quaderni di Studi e Notizie*, Vol. 11, No. 196, 1.6.1955, pp. 365-367, 2 ff.)

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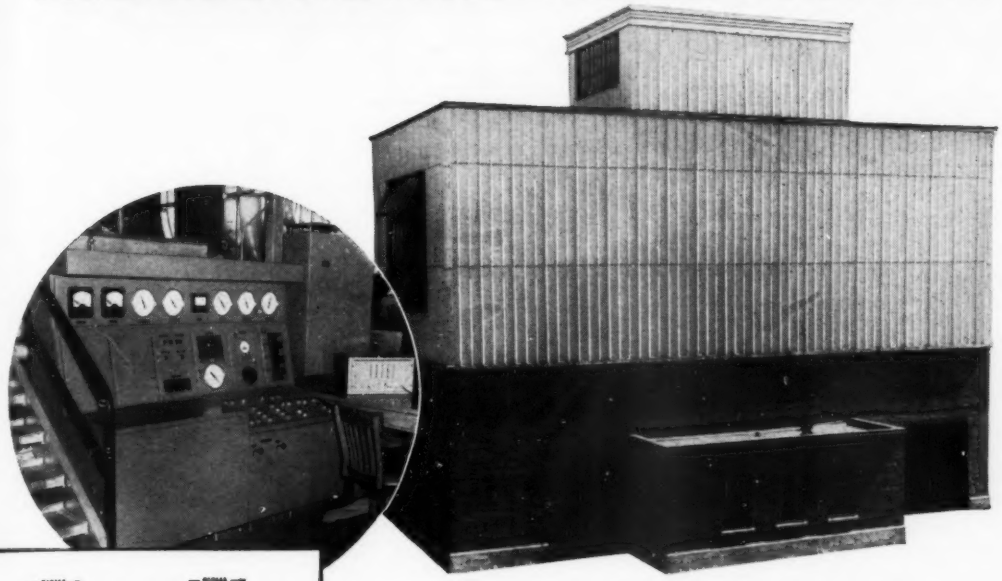

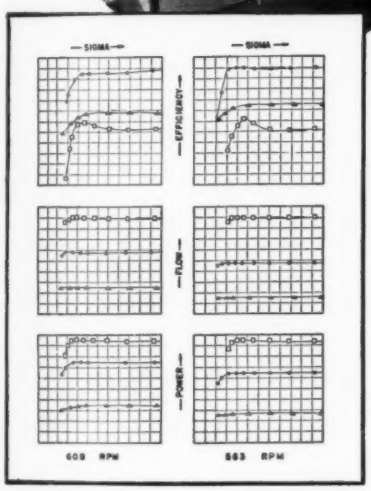

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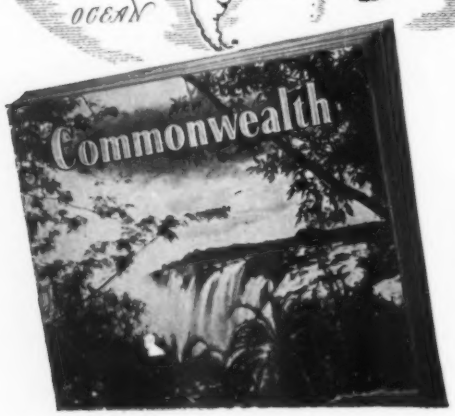

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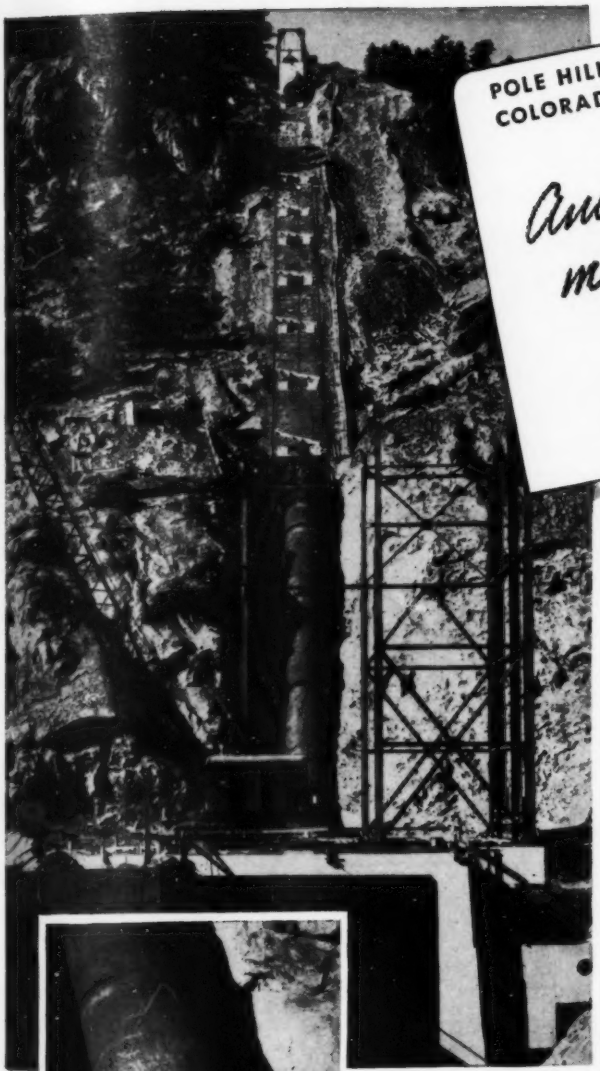

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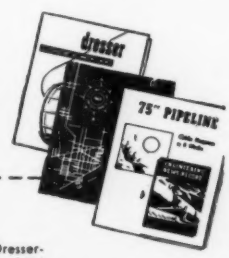

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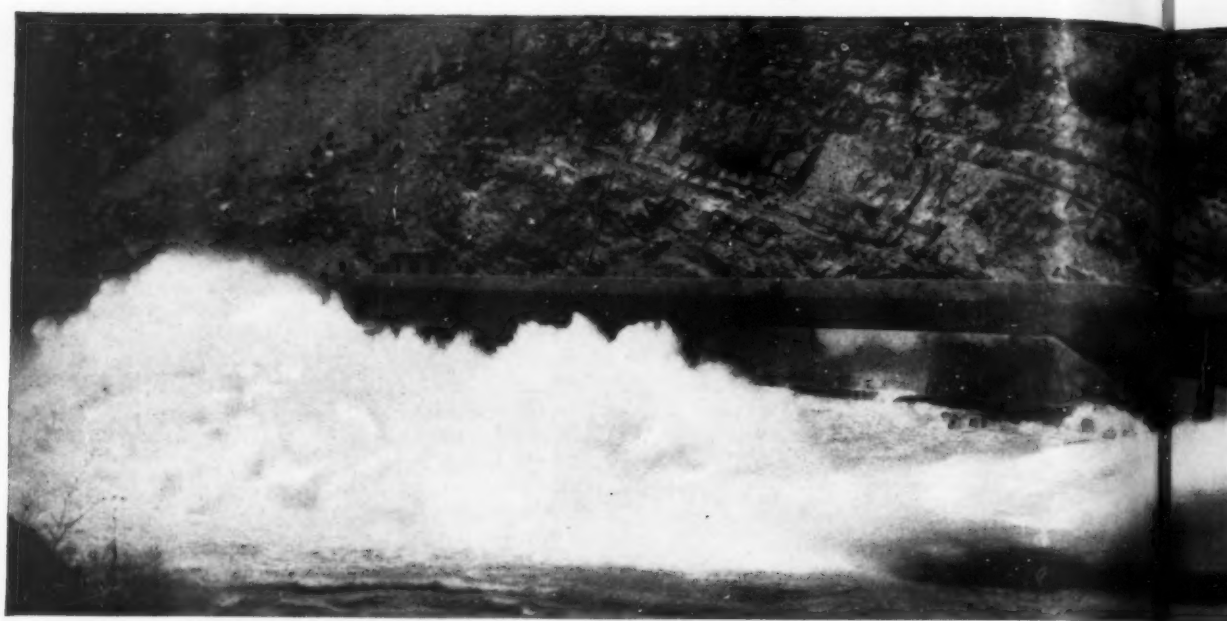

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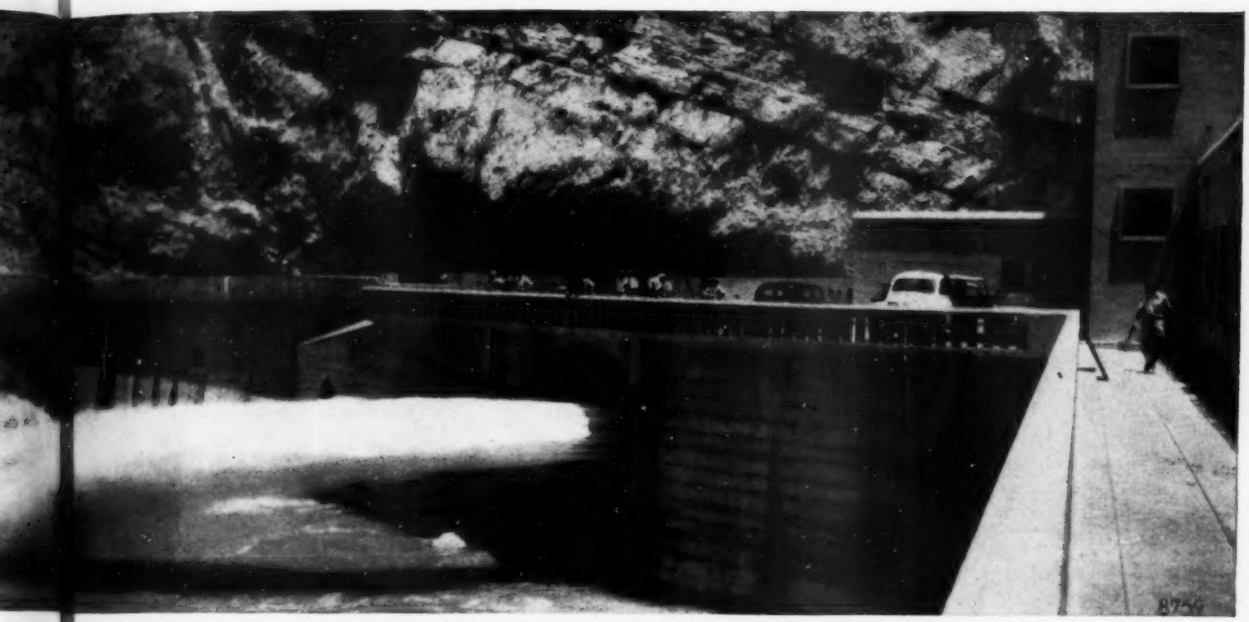

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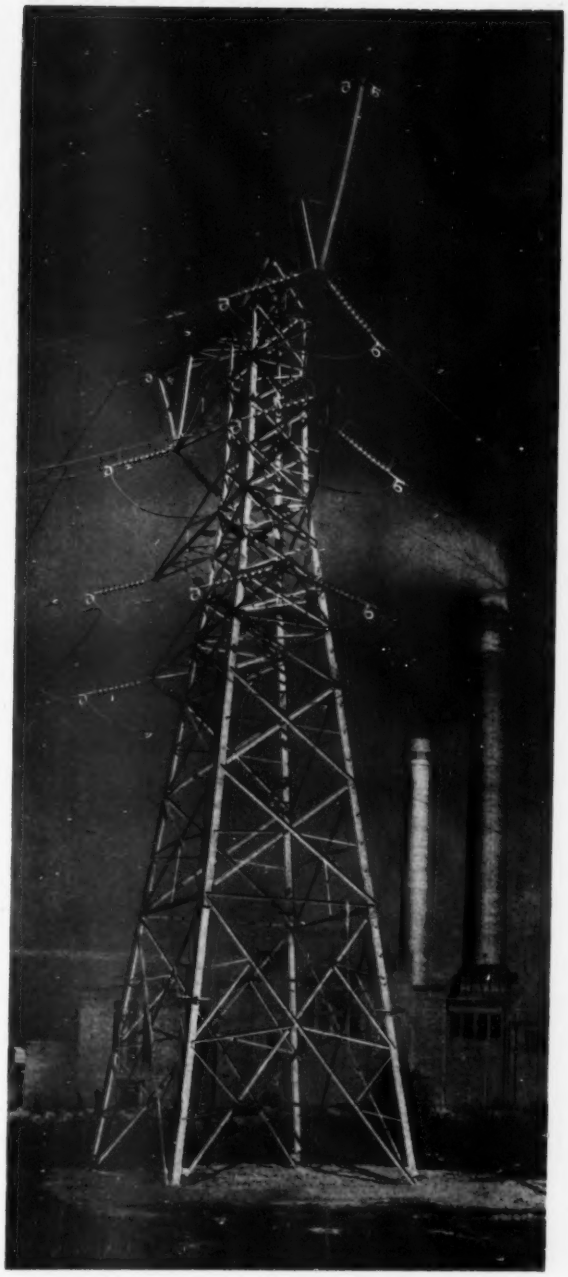

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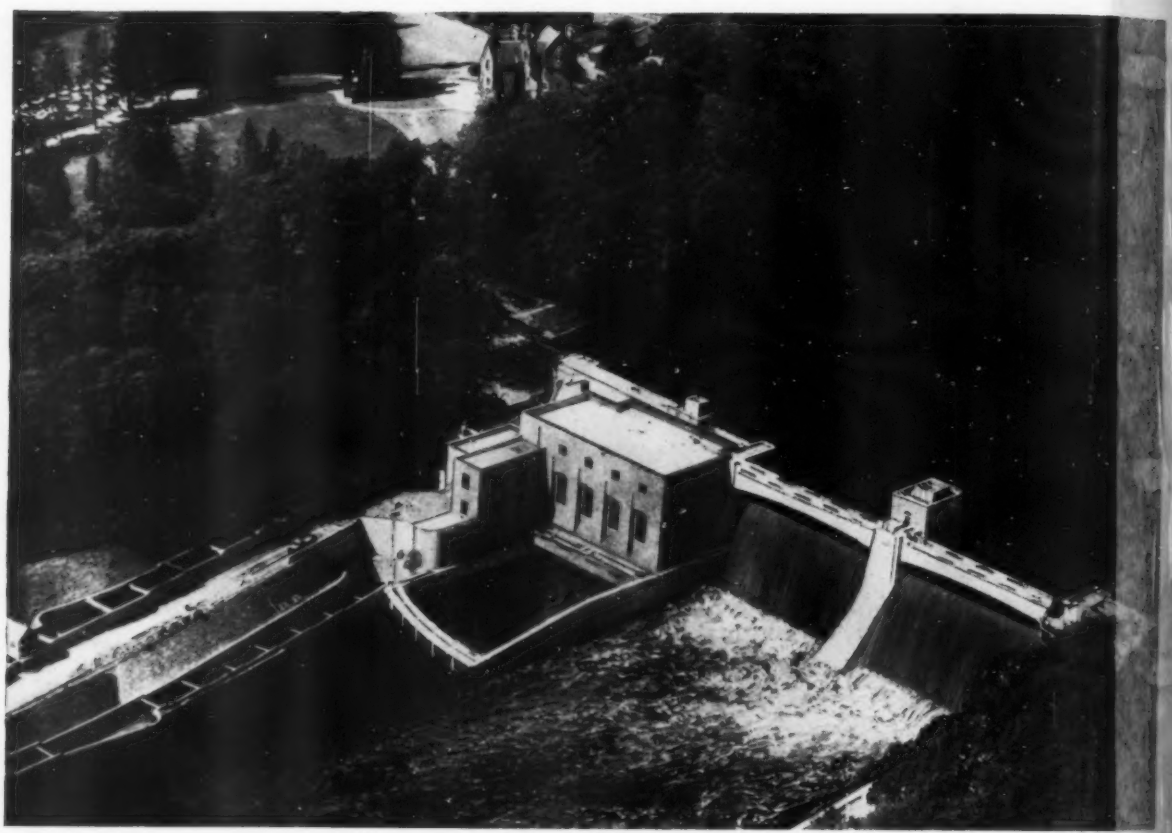

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